THERMAL IMAGING APPLICATION IN EVIDENCE SECURING

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Abstract: Physical and personal evidence are often considered in criminal literature. New scientific and technical methods and achievements are also applied in securing evidence material for the court's needs. Thus, the thermal imaging technique can be used to provide primarily physical, as well as personal proofs. The paper presents an overview of the possibility of thermal imaging application in various forensic areas, bearing in mind that the thermal imaging technique is based on the fact that the heated bodies emit the thermal radiation that is registered by the existence of different temperature fields on the recorded objects.

Keywords: proof, material proof, personal proof, thermal imaging.

INTRODUCTION

Evidence is the most important institute of criminal procedural law because the task and aim of criminal proceedings are achieved through it. Evidence is the base for drawing conclusion about truthfulness or untruthfulness of facts and it is established in the proceedings (Vasiljević, 1981). Evidence is a source of the information which points out to specified legally relevant facts and they are subjected to determination. The evidence relates to material or psychological change occurring in the connection with the commission of a criminal offence, which in itself carries the information about a criminal offence, defendant and other legally relevant facts, which is documented in the form and in a manner defined in the Criminal Procedure Code (Aleksić, Škulić, Žarković, 2004).

In the criminal process theory there are different classifications of evidence that take different criteria as the basis. Among the most undisputed is the one which creates divison of evidence based on the criterion of the nature of the evidence, i.e. type of evidentiary actions, so the evidence can be divided into personal and physical (real). According to this classification, personal evidence is

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evidence that consists of statements of specified persons and physical evidence includes physical things that can serve as evidence (Grubač, 2006).

Physical evidence can serve several important roles during the criminal investigative process. It can help establish the elements of crime, or make associations between crime scenes, offenders, victims and instruments and can function as corroborative evidence and support other evidence that establishes an issue in question (Brandl, 2004). Considering the nature and role of physical evidence, its significance in the criminal proceedings is enormous and, consequently, an authority conducting proceedings perceives it as the most reliable evidence. Therefore, special attention is paid to the detection and securing of this evidence in the criminal investigation.

The process of proving begins with crime scene investigation from the moment of obtaining operational information and appropriate traces that indicate the existing of a criminal act and a perpetrator. The team work of police officers, i.e. crime scene investigators – detectives and forensic workers, has the great importance for successful performance of criminalistics processing and clarification of some criminal act. Crime scene investigators – forensic officers -find, fix, interpret and analyze traces, while detectives collect information, which will later, in the course of the procedure, become material and personal evidence.

Physical evidence (traces, etc.) at the scene, as well as the collected information from citizens, can provide useful information in relation to the criminal act and its perpetrator which have to be checked whether they were obtained during the crime scene investigation, expertise or some other process.

Images taken with the thermal cameras are one of the most important physical evidence, since they can be a source of important information about criminal offence and/or perpetrator, and constitute ground for collecting other evidence.

THERMAL IMAGING TECHNIQUE

Infrared (IR) radiation, emitted by every object depending on its temperature, is invisible to the human eye. The wavelength of IR radiation is within the range from 780nm to 1mm in the electromagnetic spectrum. Thermal infrared radiation (wavelengths from 0.1 to 100 μm) is emitted by all matter with temperature above absolute zero and it depends on an object's temperature and emissivity only. Thermal cameras convert infrared radiation into visible radiation for human eye and it was originally developed for military applications (IR guided missiles, etc.). Thermal imaging is a nondestructive technique, which can help obtain information invisible to the naked eye (Edelman et. al., 2013). Thermal imaging means recording for the purpose of detecting energy in the area of the invisible part of the spectrum of electromagnetic radiation and its converting into a visible image (Thurman, 2006).

Thermal imaging technique is applied in cases when there is a need to measure the temperature of the object without any contact with the measuring device. Thermal image shows the temperature distribution on the surface of the recorded object. By observing and photographing an object with the use of thermal camera, it can be monitored by changing its temperature for a certain period of time. The object illuminated by infrared light emits radiation that the thermal camera registers and artificially generates colors.

The thermal camera detects the radiation of the infrared rays (the range of long infrared rays) from the recorded object, which identifies the image of the temperature fields. Thermal image, so called thermogram, is a graphical representation of the measured temperature values, where each point in the image represents a certain value. Thermal camera allows the visualization of thermal contrast because the detector of the difference in the received infrared radiation flux turns into an electrical signal that generates a visible image in proportion to the thermal contrast. Colors on the thermal camera are artificially generated in such a way that the warmer surfaces of the red shades of the electromagnetic spectrum are while the colored fields are purple, dark blue and blue. In order to measure the exact value of the temperature of the recording object, its emissivity, ambient temperature, humidity, distance from the object to the fixed point from which it is being recorded must be taken into account. Inside the device, infrared radiation is converted to visible according to the fact that the human eye does not register it (Васиљевић, 2005). The first uses of infrared sensors were recorded for military purposes in the First World War (Барбарић, 2014:3). Nowadays, this application is much wider (industry, veterinary medicine, medicine, art, etc.), which uses image analysis methods and determines statistical and deterministic parameters (Барбарић, 2014:107). An infrared imaging system consists of optical system, infrared detector, unit for signal processing, and the system for image acquisition. Also a part of thermal imaging system is personal computer with appropriate software for image analyzing. Infrared radiation detected by the lens of thermal camera is a combination of emitted, transmitted, and reflected radiation and comes from three different sources: the target object, its surroundings, and the atmosphere (Edelman et.al., 2013). The cameraman is also the source of thermal radiation, because the human body has the temperature of 36-37 degrees Celsius, which is above the room temperature. Interpretation of the image received by thermal camera should be done by an expert person who is specially trained for working with the camera.

THERMAL IMAGING IN OBTAINING OF PHYSICAL EVIDENCES

Physical evidence implies every material change arising in connection with a criminal event (Митровић & Ступар, 2002). Thermal imaging can be used to provide physical evidences in forensics and for video surveillance when there

is a need for detection of the presence of some person. Thermal imaging is used by police and security agencies as an evidence material in the cases of border crossing control, identifications of perpetrators and secure access control. Also thermal imaging can be used in identification of people by thermal diagrams of certain body parts such as face, ear, hand, etc. (Bebis et. al.,2006; Mašković et. al, 2013).

Infrared imaging can be used in forensics such as the estimation of the post-mortem time interval - postmortem cooling curve of a human body, crime scene investigation when there are blood traces on similarly colored surfaces which may be highlighted with IR light and an indication of recent human contact or the time since a thermal camera was used (Edelman, et.al., 2013). It is used in the visualization of other body fluids at the crime scene and to find possible victims in a thick smoke and dark.

Also, thermal imaging can be used for making thermal 3D model of the crime scene (Edelman & Aalders, 2018). Thermal imaging can be applied in forensic processing of the explosion scene and fire, since the explosion and fire are exothermic chemical reactions. The crater as a characteristic evidence high explosive explosion can be recorded with an infrared camera, since a large amount of heat is freed at that location. The thermal camera can be used to determine the explosion time based on the cooling rate of the crater. An example of using the thermal imaging in forensics, at the scene of explosion is given in Figure 1.

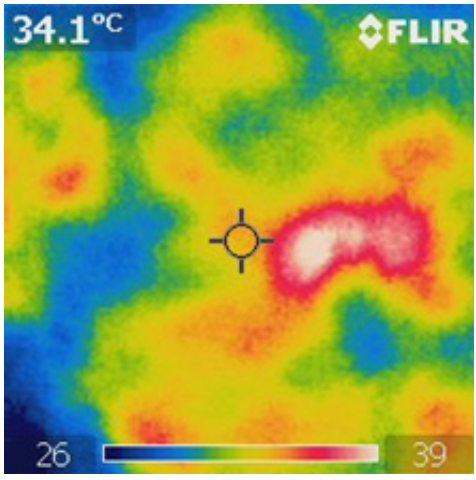

Figure 1: *Thermal imaging of the crater after explosion of TNT on soil*

In the USA, thermal imaging is dominantly used for the detection of illegal laboratories for cultivation of cannabis, as autonomous evidence in the criminal proceeding and as proof that reinforces the request for a search of specified premises. Therefore, in the practice of the US courts the question arises as to whether this evidence should be seen through the prism of the protection of the right to privacy, i.e. the Fourth Amendment to the Constitution of the US. According to

this Amendment "the people have a right to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated, and no warrants shall issue, but upon probable cause, supported by oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized". The Fourth Amendment issue raised by thermal imaging technology is whether law enforcement's use of the device constitutes a search within the meaning of the Fourth Amendment.

In the beginning, a majority of US courts have held that a thermal imaging is not a search and have accepted thermal image as evidence although the warrant for a search wasn't obtained. Majority-view courts rely on several different rationales. One rationale posits that thermal imaging is non-intrusive and, therefore, not a search. Another rationale analogizes thermal imaging to canine sniffs. Other courts reason that because thermal imaging detects heat emitted from a source, thermal imagers should be compared to cases involving the legal status of garbage placed on the curb. Finally, some courts justified the use of thermal imaging on the plain view doctrine for a search (Campisi, 2001).

Only a minority of US courts considered that for this type of evidence law enforcement officers must obtain a court warrant because otherwise it constitutes a search under the Fourth Amendment. These courts focus on the intrusive nature of this technology. Minority-view courts also focus on the individual's expectation of privacy in the activities conducted within the home, rather than on the expectation of privacy in the heat emitted from the residence. Other courts stated that the use of thermal imaging devices reveals intimate details occurring within the sanctity of the home, the place deserving the utmost protection pursuant to the Fourth Amendment (Larks-Stanford, 2000).

The Supreme Court put an end to mentioned discussion in the *Kyllo v. US* and took a stand that thermal imaging constitutes a search under the Fourth Amendment. The court stated: "It would be foolish to contend that the degree of privacy secured to citizens by the Fourth Amendment has been entirely unaffected by the advance of technology". Also, the Court noted: "Where, as here, the Government uses a device that is not in general public use, to explore details of the home that would previously have been unknowable without physical intrusion, the surveillance is a "search" and is presumptively unreasonable without a warrant" (Kyllo v. US, 2001).

Bearing in mind the fact that Serbian police officers use thermal imaging technology and the fact that Criminal Procedure Code of the Republic of Serbia (CPC) does not include any provision for the use of this evidence, the question arises whether the thermal imaginig can be used as evidence in a court. At this point it is important to note that the CPC does not prohibit the use of other evidentiary actions except those explicitly enumerated in its provisions, as it prescribes that evidence is not only collected and examined in proceedings in accordance with the provisions of the CPC, but also in other manner prescribed by law (Art. 82). This means that in the criminal proceedings evidence can be collected and ex-

amined through unnamed evidentiary actions. In support of that it is stated that the possibility to use, under certain conditions, everything that can contribute to determining the facts in the proceedings should not be denied (Ilić *et al.,* 2013). The only condition that must be satisfied is expressed by the rule that court decisions may not be based on evidence which is, directly or indirectly, in itself or by the manner in which it was obtained, in contravention of the Constitution, CPC, other statute or universally accepted rules of international law and ratified international treaties (Art. 16, Par. 1 CPC).

APPLICATION OF THERMAL IMAGING IN EVIDENCE SECURING

The theoretical assumption, based on thermal imaging in obtaining personal evidence, is a change in the temperature on the part of the face around the eyes (Baić & Areh, 2015; Ivanović & Baić, 2016), which is essential for the detection of misleading behavior. In this sense, it is assumed that a person who does not speak the truth due to tension and fear will increase the speed of blood flow in the upper part of the face (Pavlidis, Eberhart & Levine, 2002; Vrij & Grangh, 2007 according to Baić & Areh, 2015:211). As the fluid (blood) in the tube (blood vessel) increases the kinetic energy of the particles, and indirectly the pressure, it is expected that the temperature will increase. The ultra-sensitive thermal imaging camera will register the temperature change in the eye area by changing the color. The first researchers (Pavlidis, Eberhart & Levine, 2002) who noticed the possibility of using a thermal camera in recording a person's face and detecting of lies, showed, with 87% of the accuracy, that people who do not speak the truth differ from the truth-tellers. The advantages of this method are reflected in the fact that it is noninvasive, i.e. does not leave any traces on the recording object because there is no physical contact between the cameraman and the recorded person. Since this conclusion is made on a small sample (20 respondents), the reliability of the conclusion can be called into question. The other studies that have been carried out on a larger number of respondents, confirmed the percentage of reliability (Rayoub & Zwiggelaar, 2014, according to Baić & Areh, 2015:212), while the other authors reported 76% confidence (Yhu, Tsiamyrtzis & Pavlidis, 2007 according to Baić & Areh, 2015:212) and 67% (Warmelink, et.al., 2011 according to Baić & Areh, 2015:212). Research results about thermal imaging in lie detection realized in Colombia show a success rate of 79.2 % (Bedoya-Echeverry et. al., 2017). Considering the fact that this percentage is greater than 50 in all of these studies, this technique can`t be completely rejected, but this deviation must be kept in mind when making conclusions in expert evidences. When someone does the thermal imaging for the purpose of lie detection, it is possible to include several persons at the same time that can be considered an advantage of this method (Bedoya-Echeverry, et.al. 2017). Thermal imaging technique is used globally to evaluate the truth of the testimony, but not yet in Serbia,

CONCLUSION

Although the use of thermal imaging as evidence in criminal proceedings has been overwhelmed with difficulties, this technique is permitted in the USA if the probable cause and warrant are provided. In Serbian law, this evidentiary action is not specifically prescribed, but its use can be based on the rule that evidence in criminal proceeding can be collected and examined in proceedings in accordance with the provisions of the CPC and in other manner prescribed by law as long as they are in accordance with the legal order and if they do not violate basic freedoms and human rights.

Thermal imaging is the technology that is the most isolated in the field of lie detection which gives promising results. The basic advantage of the use of thermal imaging in securing evidence is that it is a non-invasive method that does not require contact between the device and the subject being recorded. Therefore, this technology does not require direct contact, when measuring physiological reactions, as in the case of polygraph testing. Problems that arise in thermal imaging are first of a technical nature, such as temperature and humidity, the distance between the person and the camera, and the impossibility of applying it when a person wears glasses (Ring & Ammer, 2012; Jones & Plassmann, 2002). Second, it is possible to cover several people simultaneously when applying the thermal imaging (Bedoya-Echeverry et. al., 2017); however, it should be taken into account that each of these objects can affect the thermal image of another object. Third, as the thermal imaging and imaging system require an ultra-sensitive thermal camera and the corresponding software and computer equipment, the cost can also be considered as a limiting factor. When using the thermal imaging, it is possible to cover several people at the same time. However, it should be taken into consideration that each of these recording objects can affect the thermal image of another object.

Considering the fact that the infrared radiation of the objects at the crime scene is conditioned by the radiation of the other objects in the environment, as well as crime scene investigators at the scene, it is necessary to interpret the thermal image from the crime scene by an expert trained to work with the thermal camera. In the application of thermodynamics in the lie detection, all of the above mentioned researchers used a percentage of confidence greater than 50, which is a sign that this technique can`t be completely rejected, but this deviation must be considered as a form of limitation in making conclusions in expert testimonies.

Bearing in mind the fact that even professionals (police officers, judges, customs officers, etc.) without the help of technical devices, such as polygraph, accurately recognize misleading behavior in only 50 to 60% of cases (Knapp & Hall, 2002) or at an average of 50% (Baić, 2010). Therefore, man's capabilities are limited in the field of lie detection and in evaluation of the truthfulness of the testimony. Thermal imaging, in a certain sense, provides the opportunity to classify statements as true or false, by the so-called discriminatory patterns involving the

detection of anxiety (increasing blood flow in the periorbital regions and the increas in the skin temperature), while the anxiety can also occur when a person tells the truth, that is why it is important to take into account individual differences in an emotional expression.

REFERENCES

1. Aleksić, Ž., Škulić, M., Žarković, M. (2004). Leksikon kriminalistike. Belgrade.
2. Baić,V., Areh, I. (2015). Detekcija laganja. Beograd: Sinapsa edicije.
3. Baić, V. (2010). Tačnost procene laganja i neverbalnih ponašanja koja indikuju laž i obmanjivanje. *Primenjena psihologija 1,* 77-89.
4. Барбарић, Ж. (2014). Термовизија – формирање и примена термовизијске слике. Београд: Академска мисао.
5. Bebis, G., Gyaourova, A., Saurabh S., Pavlidis I., Face recognition by fusing thermal infrared and visible imagery. Image and Vision Computing 24 (2006) 727–742.
6. Bedoya-Echeverry, S., Belalcázar-Ramírez, H., Loaiza-Correa, H., Nope-Rodríguez, S., Pinedo-Jaramillo, C., & Restrepo-Girón, A. (2017). Detection of lies by facial thermal imagery analysis. *Revista Facultad De Ingeniería*, *26*(44), 47-59.
7. Brandl, G.S. (2004). Criminal Investigation, An Analytical Perspective. Boston USA:Pearson Education.
8. Campisi, P.J. (2001). The Fourth Amendment and New Technologies: The Constitutionality of Thermal Imaging. *Villanova Law Review*, Vol. 46, Iss. 1, Art. 7, pp. 241-276.
9. Criminal Procedure Code of the Republic of Serbia, "Official Gazette of the Republic of Serbia", No. 72/2011, 101/2011, 121/2012, 32/2013, 45/2013, 55/2014 and 35/2019.
10. Edelman, G. J., Hoveling, R.M., Roos, Martin Ton G. van Leeuwen, and Maurice C.G. Aalders. Infrared Imaging of the Crime Scene: Possibilities and Pitfalls. J Forensic Sci, September 2013, Vol. 58, No. 5
11. Edelman, G.J., Aalders, M.C. Photogrammetry using visible, infrared, hyperspectral and thermal imaging of crime scenes. Forensic Science International 292 (2018) 181–189.
12. Grubac, M. (2006). Krivicno-procesno pravo, 4. izmenjeno i dopunjeno izdanje. Beograd: Pravni fakultet Univerziteta Union i JP Sluzbeni glasnik.
13. Ilić, P.G., Beljanski, S., Majić, M., Trešnjev, A. (2013). *Komentar Zakonika o krivičnom postupku: Prema Zakoniku iz 2011. godine sa izmenama i dopunama od 22. maja 2013. godine* (3. izmenjeno i dopunjeno izdanje). Beograd: J.P. Službeni glasnik.

14. Ivanović, Z., Baić, V. (2016). Taktika obezbeđivanja iskaza. Beograd: Kriminalističko policijska akademija.
15. Jones, B. F. & Plassmann, P. (2002). Digital infrared thermal imaging of human skin. *IEEE Engineering in Medicine and Biology, 21*, 41–48.
16. Kyllo v. US, (99-8508) 533 U.S. 27 (2001) 190 F.3d 1041, retrieved 15th May 2019 from: www.law.cornell.edu/supct/html/99-8508.ZO.html
17. Knapp, L. M., & Hall, A, J. (2002). *Nonverbal Communication in Human Interaction* (5th edition). Belmont, CA: Wadsworth.
18. Larks-Stanford, A. (2000). The Warrantless Use of Thermal Imaging and "Intimate Details": Why Growing Pot Indoors and Washing Dishes Are Similar Activities Under the Fourth Amendment. *Chatolic University Law Review*, Vol. 49, Iss. 2, Art. 8, pp. 575-612.
19. Mašković, Lj., Teodorović, S., Branković, A. Infrared thermal imaging in forensics, Thematic Conference Proceedings of International Significance "Archibald Reiss Days", Vol. III (editor in chief: Kolarić, D), Academy of Criminalistic and Police Studies, Belgrade, March 2013, p. 3–14.
20. Mitrović, V., Stupar, Lj. (2002) Kriminalisticka tehnika.
21. Pavlidis, I., Eberhardt, N. L., & Levine, J. (2002). Human behavior: Seeing through the face of deception. *Nature,* 415, 35.
22. Ring, E.F., Ammer, K. (2012). Infrared thermal imaging in medicine. Physiological Measurements. 33(3):33-46. doi: 10.1088/0967-3334/33/3/R33.
23. The Constitution of the United States, U.S. Bill of Rights, www.constitutionfacts.com.
24. Thurman, J. (2006). Practical Bomb Scene Investigation. Boca Raton: CRC Press.
25. Васиљевић, Д. (2005). Оптички уређаји и оптоелектроника. Београд: Машински факултет.
26. Vasiljević, T. (1981). *Sistem krivičnog procesnog prava SFRJ.* Savremena administracija, Beograd.