Chapter 6

Usage of Infrared-Based Technologies in Forensic Sciences

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Additional information is available at the end of the chapter

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Abstract

Infrared (IR) radiation comprises a beam located in the electromagnetic radiation family; it arises from the thermal vibrations of radiation that have longer wavelengths than visible light, but shorter wavelengths than microwave radiation. Its wavelength is between 750 nm and 1 mm. The amount of thermal IR radiation emitted by an object is associated with the temperature of the object, the surface area of the object and the spreading of light. IR-based technologies have been demonstrated as a method of evidence identification in forensic sciences in addition to many daily uses.

The combination of IR-based spectrophotometry with several techniques ushered in a new era in crime scene investigations and the identification of evidence obtained from crime scenes. Furthermore, the use of IR-based photography techniques has significant advantages. IR fluorescent automated DNA sequencer and thermal analyser for deception detection are other techniques that take advantage of IR technology.

In this chapter, we aimed to present the IR-based technologies used in forensic sciences and forensic photography techniques to define the current situation, the importance and the advantages of IR thermal imaging among these techniques, as well as to describe the operating principles of IR thermal imaging technologies that may be generated in the future based on this technique.

Keywords: Infrared, Thermal Imaging, Scene Investigation, Post-Mortem Interval, Spectrophotometry

1. Introduction

Radiation has been defined as "the emission or transmission of energy in the form of waves through space or through a material medium" [1]. Electromagnetic waves are different from sound waves because they do not require a medium for propagation. As they spread in the air and solid materials, the spread in the empty space does not contain substances [2]. It has been reported that the term radiation includes electromagnetic radiation (e.g., radio waves, visible light, x-rays and gamma radiation), acoustic radiation (e.g., ultrasound, sound and seismic waves) and particle radiation (e.g., alpha radiation, beta radiation and neutron radiation) [1, 3]. The electromagnetic spectrum is a concept that comprises all possible electromagnetic radiation based on the rules of physics anywhere in the universe and the relative locations of this spectrum according to the wavelength or frequency of different radiation derivatives [4, 5].

Infrared (IR) radiation comprises a beam located in the electromagnetic radiation family that arises from the thermal vibrations of radiation with longer wavelengths than visible light, but shorter wavelengths than microwave radiation **Figure 1**. Its wavelength is between 750 nm and 1 mm, and its frequency is between 300 GHz and 400 THz [5]. The amount of thermal IR radiation emitted by an object is associated with the object temperature, and IR may be used to remotely determine the temperature of an object [6]. IR radiation is also referred to as thermal radiation and is defined by three groups. Far IR radiation is between 300 GHz and 30 THz frequency and between 1 mm (=1000 μm) and 10 μm wavelength. Mid-IR radiation is between 30 and 120 THz frequency and between 10 and 2.5 μm wavelength. Near-IR (NIR) radiation is between 120 and 400 THz frequency and between 2.5 μm (=2500 nm) and 750 nm wavelength [2, 5].

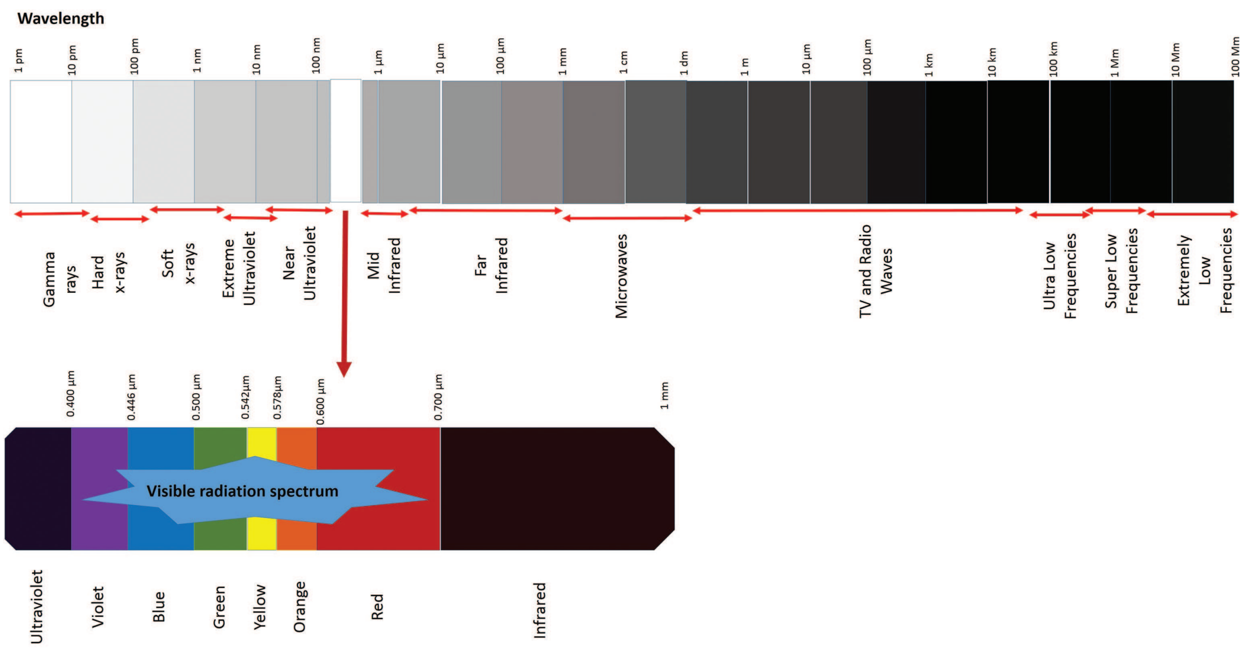

Figure 1. Location of infrared radiation in the electromagnetic spectrum.

2. Brief history of IR radiation

The interaction of light with matter has attracted attention for 2000 years. First, Claudius Ptolemy (100–170, who was known as a mathematician, astronomer, geographer, astrologer and writer) defined the refraction of light in objects in the early 1300s. In 1305, Theodoric of Freiberg (1250–1310, who was a theologian and physicist) created a simulation rainbow with water-filled glass spheres [7].

For the first time in history, IR radiation was defined by Frederick William Herschel (1738–1822, who was a British astronomer). In his studies in the 1800s, he discovered radiation in sunlight by passing it through a prism and holding a thermometer just beyond the red end of the visible spectrum. This radiation was referred to as "below red". This below red radiation was described as IR radiation in subsequent years [8–10].

In 1905, William Weber Coblentz (1873–1962, who was a German physicist) demonstrated that certain molecular groupings, currently referred to as functional groups, had absorbed specific and characteristic IR wavelengths, and he recorded the spectrums among 1–1,15 micrometres of several hundred functional groups [7, 11]. In the first half of the twentieth century, many scientists expanded the spectral database of organic compounds and determined the specific spectral properties of functional groups [7].

2.1. Brief history of IR imaging

In 1829, Nicéphore Niépce (1765–1833, who was a French inventor) and Louis-Jacques-Mandé Daguerre (1787–1851, who was a French artist and photographer) had developed a photographic plate sensitive to NIR radiation. Based on this invention, Sir William de Wiveleslie Abney (1843–1920, who was an English astronomer, chemist and photographer) and Edward Robert Festing (1839–1912, who was an English army officer and chemist) performed NIR radiation measurements in history [7]. In 1860, Gustav Robert Kirchhoff (1824–1887, who was an American physicist) recorded the atomic spectra of many elements and defined that "a hot solid object produces light with a continuous spectrum, a hot tenuous gas produces light with spectral lines at discrete wavelengths (i.e., specific colors) which depend on the energy levels of the atoms in the gas and a hot solid object surrounded by a cool tenuous gas (i.e., cooler than the hot object) produces light with an almost continuous spectrum, which has gaps at discrete wavelengths depending on the energy levels of the atoms in the gas" [12]. Kirchhoff's law of thermal radiation, Stefan-Boltzmann law, Planck's law and Wien's displacement law defined four basic laws of IR radiation [13].

The first thermal camera was invented by Kálmán Tihanyi (1897–1947, who was a Hungarian physicist, electrical engineer and inventor) in 1929. It was used for anti-aircraft defense in Britain [13, 14]. An evaporograph, which is considered the ancestor of thermal imaging, was initially discovered in 1956. In this technique, a thermal imaging device converts an IR image into a visible image via the differential evaporation or condensation of oil on a thin membrane [15].

In the following years, especially after the year 2000, the IR image capture conversion kits of digital cameras began to be developed. In 2006, the first professional digital camera, which was developed using ultraviolet (UV) and IR technology, was introduced [16].

3. Usage of IR-based technologies in daily life and reflections on forensic science

To date, IR-based technologies are a component of daily life. This technology is used in many applications in automotive technology, the petroleum industry, photography techniques, the security sector, agricultural inspection, the forestry sector and medical applications.

3.1. Usage of IR-based technologies in automotive technology

In terms of driving safety, IR-based technology comprises a method that may be used routinely in the future. Currently, it is used by a limited number of companies. One of these systems is based on NIR integration on the basis of existing head-up display systems in vehicles. This system aims to warn of car drivers using a screen in connection with a NIR camera mounted in the front bumper. The NIR camera will distinguish cars, people, animals and other objects on the road, especially at night, based on their heat. One reason for the lack of routine use of this system is that IR cameras transfer images from only 100 meters [17]. It has been indicated that the IR cameras may be used for passenger safety and comfort. IR cameras enable data to be obtained, such as whether there is a seat passenger and the estimated weight if there is a passenger, especially in a bus. In light of these data, equipment based on NIR and IR may be added to vehicles, such as an adjustment system for the air bag pressure according to passengers, indicators regarding accurate issuance of the seat belt warning, passenger-oriented climate control systems, a radar based mass movement sensor for automotive security applications, a driver monitoring system that warns a fatigued driver to pull over and rest, advanced driver assistance systems, including features such as a lane departure warning and switching between autonomous and manual driving mode and systems that disable the vehicle in situations such as drunk driving [17–20]. These systems that improve vehicle safety will cause a decrease in the number of traffic accidents, as well as the number of deaths and injured individuals in traffic accidents. Thus, this system will be an important service for preventive medicine, which is an important task in forensic science.

3.2. Usage of IR-based technologies in petroleum industry

One key area that utilizes IR has been the refinement of petroleum products. In the production of rubber, relatively simple techniques have been used for the analysis of C_4 hydrocarbons. NIR spectroscopy has been used for petroleum refining, especially for petrochemicals and polymers. The major advantages of NIR spectroscopy include its fast, non-destructive and easy approach to extend to online analysis in conjunction with optical fibers. Based on these advantages, oil companies have used IR spectrophotometry and Raman spectrophotometry for the online control of product quality [21, 22].

Spectroscopy is a specific analytical technique used in the structure determination of organic compounds. This technique assesses the changes in the wavelength of the radiation, which was passed from the material to be examined, and measures the amount of radiation absorbed in different wavelengths by the material. As a result of the substantial number of different absorption bands in the spectra of organic substances, organic substances are facilitated to be compared with each other. The spectrum of an organic substance is similar to its fingerprints, and there are no two different substances that provide the same absorption spectrum in theory. Utilizing the originality of the IR spectrum of the substances, qualitative and quantitative analyses may be performed via IR spectrophotometry [23, 24]. IR spectrophotometry has been used in several areas of forensic sciences. NIR spectrophotometry may be used for the determination of ignitable liquids, which are used as accelerants in forensic laboratories. The use of these techniques in forensic science is subsequently described in detail in the section under "Usage of IR-Based Technologies in Forensic Sciences".

3.3. Usage of IR-based technologies in photography techniques

Each object that has a temperature above absolute zero (0° Kelvin, −273°C) emits radiation in the IR region [6]. The IR spectrum is broad from the visible radiation spectrum. IR radiation is related to object temperature, and the IR radiation emitted by objects increases when the object temperature increases. This IR radiation ensures the visibility of objects without lighting. In thermographic imaging, emission, transmission and reflection occur via heat transfer between the camera and the object [25]. A thermographic camera detects changes in temperature as a result of this radiation in the range of the electromagnetic spectrum from 0.9–14 μm [6, 13]. On the basis of thermal camera imaging, the reflected differences in temperature transfer the image [6]. Several conditions are necessary to create the images of thermal cameras. Thermal camera imaging may be used for objects that have different heat conductivities, objects that have the same emissions but different heat, objects that have the same heat but different emissions, objects that have radiation reflection or the same objects under different weather conditions [14]. The non-contact IR thermography (IRT) technique comprises a non-destructive inspection method. It uses IR irradiation to identify and record the thermal pattern and temperature that spread across an object surface. This equipment converts temperature by sensing IR radiation, and it provides the converted image of this distribution [6].

Typical IR cameras include semiconductors to detect IR energy from the target object and cooled detectors. The typical IR camera signal processing mechanism may be summarized as follows: (1) the image is created using radiation in the IR wavelength range by the optical system; (2) radiation detected by the thermal detectors is converted into electrical signals via the thermal detectors; (3) some systems require the scanning mechanism, whereas other systems do not require, in general, a large detector array to completely cover the field of view of the camera; and (4) an electrical signal is converted to a video signal by the electronic processor, and an image is formed by transmitting the video signal to the display unit [6, 26].

In general, IR cameras use a single sensor, and they do not differentiate different wavelengths of IR radiation. Color is not significant in areas outside the visible wave lengths. Color IR cameras have a more complex structure. In these cameras, the colors used in the camera structure are pseudo-coloring, which demonstrate changes in the incoming signals [6].

IR cameras with uncooled detectors were implemented after 1990. In the following years, the prices of IR cameras steadily decreased, and their usage was widespread as the parallel of the rapidly developing technology [26]. IR imaging is an important technique used in forensic science, especially crime scene investigations. The use of these techniques in forensic science is described in detail in the section under "Usage of IR-Based Technologies in Forensic Sciences".

3.4. Usage of IR-based technologies in security sector

Several techniques based on IR radiation have been used in security sectors. Examples of these techniques are as follows.

3.4.1. Personal identification by IR-based technologies

Personal identification systems have been used to identify individuals in situations that require security in the entrance of the building or building parts. The most important component of the palm vein authentication systems, facial recognition systems, iris scanning systems, smart surveillance systems, IR finger imaging systems and palm print recognition systems comprises IR cameras [27, 28]. These techniques are important tools for crime prevention, as well as the arrest of criminals in forensic sciences.

3.4.1.1. Palm vein authentication systems

The heat pattern of the human body may easily be determined by IRT. The heat pattern of veins in the human hand is specific to each individual. Thus, the structure of the hand veins may be determined, and private ciphers may be created [28, 29]. Sarkar et al reported that "the red blood cells (hemoglobin) present in the veins absorb the rays and show up on the map as black lines, whereas the remaining hand structure shows up as white" [29]. Some companies have begun to use palm vein authentication systems in automatic teller machines (ATMs) worldwide. These systems have also been used in the entrance into a country from the airport, as well as the entrances of several security buildings.

3.4.1.2. Facial recognition systems

Facial recognition systems consist of three modules, including image acquisition, face recognition and face matching. In this system, visible light, IR light and thermal cameras are used to obtain a three-dimensional image and improve the image resolution [29].

3.4.1.3. Iris scanning systems

The iris is in a position to be seen at first glance and is easily defined in the IR cameras and visible-light cameras. Therefore, the iris may be easily used in automatic recognition systems.

In this system, cooperation in the placement of the eye in the correct place of the device is sufficient [27–29].

3.4.1.4. Smart surveillance systems

Smart surveillance was defined as the use of automatic video analysis technologies in video surveillance applications. To date, digital video surveillance systems are one of the most widely used types of systems. The tasks are to capture, store and distribute a video. The task of threat detection has been the duty of human operators [30].

However, Prokokski reported that "IR identification smart surveillance systems will provide the ability to automatically survey an area in the dark, find each face within the scanned area, and match it against a Watch List of visible images". Smart surveillance systems will provide important advantages for the security of society. They may be used to monitor criminal suspects and high-density crime areas, control the parole or access of high crime-prone offenders to restricted areas and check for terrorists on watch lists when they enter airports, custom areas or courts [27].

3.4.1.5. IR finger imaging systems

Lee et al. reported a new technique that includes recognition accuracy compared with the use of only finger vein patterns by logically including both finger vein and finger geometric components. In this technique, both the finger pulp and the finger dorsum are examined [31].

3.4.1.6. Palm print recognition systems

Palm print has been defined as a unique and reliable biometric characteristic with high usability. The principle of this technique was defined using a palm line orientation code as features. The use of NIR techniques obtained better results than traditional methods. The reason for this difference was that palm vein structures are visible when NIR is used [32].

3.4.1.7. Talking head video compression

During speech, some muscles of the face form facial expressions that may be seen as movements. The coding of these facial muscle movements during some applications, such as videophone, videoconferencing, video email, synthetic speech and face animation by the use of IR cameras are considered as new methods of personal identification to be used in future years [27].

3.4.2. Computer security by IR-based technologies

Computer security systems associated with IR cameras obtain real-time images of the user, give permission to the user to enter the system and define its user authorities. These systems may automatically turn off or lock the computer, and they may apply the commands with head movements by following the movements of the user's head and body [27]. This technique may be used to prevent computer crime.

3.4.3. Fire security by IR-based technologies

Most industrial fires occur from electrical short circuits. An important application of the IR imaging technique has been defined as the inspection of high-voltage installations, which cannot be easily accessed because of the high risk [14]. This technique is one method for determining the cause of fire.

3.5. Usage of IR-based technologies in agricultural inspection

NIR applications, especially NIR spectroscopy, have been used for the analysis of forages and feedstuffs, small grain crops, oilseeds and coarse grain, coffee, tea, spices, medicinal plants, aromatic plants, and related products, fruits and vegetables, sugarcane, cereal food products, baking products, beverages and brewing products, fats and oils, dairy and eggs, meats, timber and paper, animal by-products, wool, cotton and soils [33]. NIR spectroscopy has been used to evaluate the parameters for estimating the maturity of different fruit species, check the ripening status of fruits on trees or grade fruits in the packing house, assess fruit quality, such as sugar and acid contents, soluble solids, firmness of fruit, decide when to harvest and select the quality and suitable seeds in breeding programs [34]. This technique is used in forensic sciences to identify counterfeit food products.

3.6. Usage of IR-based technologies in forestry sector

The applications of NIR Spectroscopy have been used for the non-destructive quantitative analysis of the solid wood density, the moisture condition and the lignin content in the bulky wood of trees, to predict the stage of decay of decomposing leaves and for biosecurity inspection [34]. Investigations of allegations of illegal tree cutting may take advantage of this application in forensic sciences.

3.7. Other non-medical uses of IR-based technologies

In the construction sector, IR imaging has been used for the thermal assessment of buildings, such as the determination of the requirements of ground insulation, the evaluation of the adequacy of isolations, the evaluation of the humidity level of buildings and the detection of hot and cold air entered or exited outside from doors and windows. It is a screening tool used to determine the durability of buildings [35]. In forensic sciences, this method provides a significant contribution to the determination of building durability in the case of buildings that collapsed because of an earthquake or structural problems.

IR imaging is an important application for electrical engineers. Electric current that passes through the resistance element generates heat. Thus, electrical engineers may determine incorrect connections, internal damages, high resistance connections, corroded connections, oxidation, internal fuse damage, internal circuit breaker failures, high-voltage switch failures and insulation faults in an electrical circuit. The determination of engine warming via IR imaging and the activation of the cooling system increases the motor efficiency. This system facilitates engineers and forensic examiners in many engineering fields [14].

Missiles that focus on heat using IR sensors have been constructed, and missile systems have been developed to follow the heat emitted by aircrafts [9].

3.8. Usage of IR-based technologies in medical applications

Digital infrared thermal imaging (DITI) is an IRT method used to determine radiation between 8 and 14 μm emitted from the skin surface and for mapping the heat on the body surface with 0.01°C sensitivity. In this method, heat emission may be detected from the skin surface to 6 mm in tissue depth. Thus, the body heat pattern may be determined. To date, the usage of DITI has become widespread because it does not contain a high-dose radiation risk, it is painless, there is no contact with the patient during application, it has an ability for security usage in pregnant women and children, and it enables fast, easy and comfort usage. DITI is used for specific diagnostic methods or auxiliary diagnostic methods in several illnesses. DITI was defined as an auxiliary diagnostic method for the early diagnosis of several illnesses as early as 10 years ago [5, 36].

Several medical application areas of IRT are subsequently presented.

3.8.1. Screening of breast cancer

IRT was approved by the U.S. Food and Drug Administration in 1982 as an auxiliary diagnostic method for breast cancer screening. It has been reported that abnormal findings in IRT indicate 10 times more cancer risk compared with family history. In this illness, the rate of early diagnosis is 95% with a multifocal medical approach, which includes physical examination, IRT and mammography findings [37].

3.8.2. Screening of diabetic neuropathy and vascular disorders

IRT has been defined as a fast and reliable diagnostic method for neuropathies and vascular disorders in diabetes [38]. Thermoregulatory disorders in feet comprise an early sign of sympathetic dysfunction in diabetic patients [39]. It has been reported that "diabetes at-risk subjects have a significantly increased mean foot temperature (30.2 ± 1.3°C) compared with normal subjects (26.8 ± 1.8°C)" [38].

3.8.3. Usage in Raynaud's phenomenon

IRT was initially tested in 1991 for the diagnosis of Raynaud's phenomenon to determine temperature differences, which is one of the pathognomonic signs of this phenomenon [37]. In 1998, von Bierbrauer. et al reported that DITI is a useful tool in the diagnosis of Raynaud's phenomenon in vibration-induced white finger, which is an occupational disease and is triggered by vibration and/or cold exposure [40].

3.8.4. Usage for body temperature monitoring

Methods based on IRT have been used for body temperature screening of a population in public spaces, such as airports and bus terminals, to prevent the spread of epidemics, such as severe acute respiratory syndrome (SARS), avian influenza and swine influenza [38].

3.8.5. Usage for diagnosis of skin diseases

In general, skin diseases have an inflammatory origin. One of the diagnostic signs of these diseases is a temperature increase in the skin surface. Thus, IRT has been accepted as a reliable method for the diagnosis of skin diseases [38].

3.8.6. Usage for diagnosis of rheumatic diseases

IRT has been defined as a reliable diagnostic method of diseases characterized by local temperature increases, such as rheumatoid arthritis, inflammatory arthritis, gut, tennis elbow, fibromyalgia, acute muscle injuries and spasms, enthesopathies and complex regional pain syndrome [38, 41].

3.8.7. Usage for diagnosis of ocular diseases

In medical studies using IRT, an ocular temperature increase was determined in patients with ocular diseases, such as anterior uveitis, hyperemic bulbar conjunctiva, post-herpetic neuralgia, Graves' ophthalmopathy, glaucoma and dry eye syndrome [42, 43].

3.8.8. Usage for diagnosis of pain

IRT is also used to determine the body's painful point. Gratt et al. classified temperature differences in patients with oropharynx pain following their 6-year clinical assessment. They reported that "patients with 'hot' thermograms had the clinical diagnoses of sympathetically maintained pain, peripheral nerve-mediated pain, temporomandibular joint arthropathy, and maxillary sinusitis. Subjects with 'cold' thermograms were demonstrated to have the clinical diagnoses of peripheral nerve-mediated pain and sympathetically independent pain. Subjects with 'normal' thermograms were demonstrated to have the clinical diagnosis of cracked tooth syndrome, trigeminal neuralgia, pretrigeminal neuralgia, or psychogenic facial pain" [44]. Furthermore, the linear-polarized near-infrared light irradiation (LPNIR), a non-invasive method, was defined as a relief treatment for patients with chronic pain from frozen shoulder, osteoarthritis, rheumatoid arthritis, post-herpetic neuralgia and other disorders [45].

The medical applications of IR-based technologies may help forensic scientists in medical malpractice claims, provide a preliminary diagnosis of the cause of death and detect the signs of trauma.

4. Usage of IR-based technologies in forensic sciences

Fast, accurate and complete application in forensic analysis are of substantial importance for the delivery of a right to the justified person, as well as the fast, accurate and complete manifestation of justice. In this context, many forensic analysis methods have been improved and implemented in the previous century. Spectrophotometric methods were developed in parallel to the developments in optics and microscopy. Since the end of the twentieth century, the use of technologies based on IRT and IR spectrophotometry has been an important cornerstone [36]. Physical evidence obtained by IR photography provides critical clues for investigators in crime scene investigations. One advantage of this evidence is that it is suitable for re-examination after a long time [16]. IR imaging has been defined as two categories, including passive IR imaging and active IR imaging. Passive IR imaging may be used to detect non-contact radiation, without an external energy source. In this method, heat traces left by humans and objects may be investigated. Active IR imaging requires external heating or cooling of objects prior to imaging. While the external heat or cool source may be a component of the system in some applications, they profit by heat of a human body, domestic heating or air-conditioning system in some applications [46]. Currently, IR spectrophotometry has been used to analyse general polymers and materials, such as fibers, coatings, tapes and adhesives [36]. Chemical imaging, including visible-near IR chemical imaging, macroscope, in addition to the visible chemical imaging macroscope, visible chemical imaging microscope and light sources and liquid tuneable filter specification techniques have been defined as methods with substantial potential for the forensic analysis of materials, including paints, tapes and adhesives, inks and firearm propellants [47].

In this section, the use of several technologies based on IRT and IR spectrophotometry in forensic science is described.

4.1. Detection of post-mortem interval

It has been reported that IR cameras that use passive IR imaging technique may be a substitute for traditional rectal thermometers for the estimation of the post-mortem time interval; moreover, these cameras eliminate the risk of contamination and the potential loss of evidences of sexual assaults [46].

4.2. Detection of tire prints

Invisible prints of objects, such as tires on clothes, may be determined using IR photography. Tire prints found at a crime scene have been matched with a suspicious vehicle, and a match was identified [48].

4.3. Differentiation of gunshot residues

In a study performed using a VSC 2000 system to determine gunshot residues on dark clothing in 2006, as well as another study performed using a modified Griess test to determine gunshot residues on dark or multicolored clothing in 2006, researchers suggested that the use of IR or

IR-enhanced photography may enhance the gunshot residue pattern [49, 50]. In a study performed in 2007 by Lin et al., gunshot residue was collected from dark cloth samples following firing from 15, 30 and 60 cm ranges using a 9-mm pistol (Smith & Wesson) with 9-mm bullets (NPA 01 3). Components that absorb the IR of gunshot residue were determined. The authors indicated that "the number of black particles observed using IR was approximately 418, 317 and 63 within a 10 cm radius around the entrance hole when the firearm was discharged at distances of 15, 30 and 60 cm of shooting, respectively". Other features of this assay for the determination of distance shooting are that this test permits records and is not destructive for gunshot residue [48]. In another study, Patne et al. claimed that chemical imaging technology may be used to eliminate different brands of ammunition based on the fluorescence characteristics of the propellant grains on clothes without destroying the evidence before further analysis may be conducted [47]. Furthermore, Bueno et al. suggested the use of NIR-Raman microspectroscopy combined with advanced statistics to detect gunshot residues in 2012. Researchers claimed that NIR Raman microspectroscopy has the potential for reagentless differentiation of gunshot residues based on forensically relevant parameters, such as the calibre size, and this method should have a significant impact on the efficiency of crime scene investigations when fully developed [51].

4.4. Differentiation of blood stains

Blood is a substance that absorbs IR rays.

Yazımı düzeltilmiş şu sorgu için çevirileri görüyorsunuz: Dolayısı ile olay yerinde ***kızılötesi*** dalga boylarını kaydeden bir cihaz kullanılması neticesinde kan lekelerinin fark edilebilirliği artmaktadır.

Yine de girdiğiniz şu sorguyu mu aramak istiyorsunuz? Dolayısı ile olay yerinde kızıl ötesi dalga boylarını kaydeden bir cihaz kullanılması neticesinde kan lekelerinin fark edilebilirliği artmaktadır.

Thus, the differentiation in the availability of blood stains in crime scenes increases when using a device noting IR wavelengths. This method is advantageous for precisely determining the morphology of blood stains. Furthermore, this method reduces the number of samples obtained from the crime scene depending on the quicker determination of materials at the crime scene and prevents the time spent and economic losses [16, 52]. Two studies demonstrated that in the detection of blood stains with an IR camera, better results were obtained by other methods even in blood stains 10-times diluted or found on the floor, which absorbs blood [16, 52]. In another study performed by Lin et al., blood stains diluted to a 1/8 ratio were viable in 8 of 10 different cloth samples by IR photography. Nevertheless, blood stains diluted to a 1/2 ratio were not viable in two fabric types, including 35% rayon and 65% polyester and 5% lycra and 95% cotton, via IR photography [48].

It has been reported that the determination of blood samples and the identification of their ages on fabrics are possible using IR cameras. In the identification of the ages of blood samples, the cross-validated standard error of calibration was less than 1 week in optimal conditions [53].

4.5. Analysis of explosives

Fourier transform infrared (FTIR) and Raman spectroscopic techniques have been defined as powerful techniques used for the optimal identification of a broad range of explosives and related compounds. It has been reported that FT-Raman spectroscopy, which has a longer wavelength, is the preferred method for the fluorescence-free analysis of explosives when the conventional Raman spectra cannot be measured because of the fluorescence background [54].

4.6. Determination of blunt force injuries

The presence, extent and pattern of contusion in victims with blunt force injuries have been defined as important evidences in the determination of the manner of death, individual abuse and sexual assault and identification of the striking object. The presence of situations such as skin opacity, surface texture and pigmentation, overlying abrasions and erythema may comprise an obstacle to a correct evaluation of skin lesions. IR radiation may penetrate the skin and be selectively absorbed by the blood. Thus, the determination of subdermal hematomas is possible using IR-imaging. IR-photography may be used to interpret and analyse traumatic injuries, determine the pattern of blunt force injuries and identify real abrasions from surface interferences, such as abrasions, lividity, dark pigmentation and post-mortem and artificial injuries. Furthermore, when an incision is not an option, IR-photography is an invaluable technique in forensic examinations of living victims of domestic violence, rape/sexual assaults and motor vehicle accidents [55].

4.7. Determination of bite and tooth marks

Human teeth may leave characteristic prints on the human body or objects. These prints are referred to as bite marks when associated with only the skin and bite injuries when the bite perforates the skin and passes through to the subcutaneous tissues. Tooth prints on foods, wood, plastic or metal objects are referred to as tooth marks [56]. In general, a human bite mark comprises a 2–5 cm oval or circular mark, which is shaped as two opposing concave arcs with or without associated ecchymosis [57]. One method for the determination and recording of bite marks and tooth marks is IR photography. In the photography of non-visible light images, IR and/or UV photography techniques may be utilized. When using these techniques, bruises that are no longer visible to the naked eye may be detected [56–58].

4.8. Fingerprint identification

One of the most common methods used by forensic experts at a crime scene is the identification of fingerprints. The pattern of ridges formed on the tips of human fingers has long been regarded as unique to each individual. In a straightforward IR chemical imaging technique, procedures such as the sample preparation, derivatization or addition of fluorescent antibodies are not required, and fingerprints in a crime scene may be converted to images and made searchable in a database [59]. Williams et al. reported that the latent fingerprints of children may be recovered after extended periods of time have elapsed using Fourier-transform IR microspectroscopy [60]. This technique has been used for adults, and successful results were obtained [25]. King et al. demonstrated that the use of a novel powder that emits fluorescence in the NIR indicated high-contrast fingerprints with excellent ridge detail on polymer banknotes and magazine pages [61].

4.9. DNA analysis

As a result of the differential arrangements of each individual's DNA molecules and the construction of fast separation of these differences via an IR fluorescent automated DNA sequencer, DNA mapping may be rapidly performed. The use of this technique may enable the determination of who the DNA belongs to without losing time [62].

4.10. Forensic document examination

IR spectroscopy and X-ray diffraction techniques may quickly determine the types and rates of molecules in a paper structure without causing damage to or installing contact with examined materials. These two techniques enable the detection of variations in the structure brought about by different processing parameters, manufacturing conditions and formulation of additives [63]. The differentiation of photocopy documents and documents published in printer toners may be discriminated by reflection-absorption IR spectroscopy [64]. In a study performed by Merrill et al., many toners of photocopies and printers have different IR spectrums. When these differences are recorded in a system and compared with a spectral library, it is possible to identify the make and model of a copy machine or obtain a list of machines that use toner with comparable spectral characteristics [65]. It has been demonstrated that places with unreadable eyes in burned documents may be read using an IRT technique [16, 48]. In studies regarding inks and paints, it was determined that individual inks and paints have different spectral characteristics. If there was a spectral library of inks and paints, a questioned document may be examined based on the pen type used in the construction of a document or spuriousness of a picture or document [66–69]. Erasures and changes on the documents may be determined using technologies based on IR techniques [16, 67]. Technologies such as VSC 2000, VSCHR, VSC 5000, VSC 6000, Forensic XP 4010 and Forensic XP 4010 D have been used for forensic document examination [67]. One study investigated the detection of writing on fabric, in which three different black pens (fountain pen, ballpoint pen and permanent marker) were signed on three different black fabrics. The researchers reported that these invisible signs became visible using IR imaging. They determined that "fountain pen ink could be visualized using IR light less effectively than the permanent inks but was recorded on considerably more occasions than the ball point pen" [39]. During this examination, a lack of destruction on the examined document, facilities for simultaneously analysing all substances on the entire material and the repeatability of the method were defined as advantages of these techniques [47].

4.11. Determination of tattoos

IR imaging has been defined to detect tattoos that have been ablated by lasers, as well as an assisting method for the identification of known criminals and organized crime groups [69, 70]. Starkie et al. reported that IR reflectography was beneficial in the investigation of tattoos post-mortem in corpses, which included partial mummification and skin discoloration [71].

4.12. Other usages in forensic sciences

Spray paints [68], paints [47, 69], multilayer paint coats [72], adhesive tapes [47, 73], soils [74], the identification of drugs and added adulterants, drugs dissolved in alcohol, drug residues on clothing, drugs in herbal medicines and the quantification of cocaine-added adulterants [75] may be analysed using spectroscopic methods based on the IR spectrum. Schotsmans et al. reported that IV cameras are useful to determine mass graves and buried human remains [76]. Sumriddetchkajorn and Somboonkaew defined a polygraph (lie detector), which was referred as the thermal analyser, for deception detection. This system analyses far-IR data obtained remotely from a suspect around the eyes and nostril areas during interrogation and records thermal changes in these regions [77].

5. Future of IR-based technologies in forensic sciences

With the enhancement of the spectrum of IR techniques and the development of the detection ability of appliances, hematomas in deeper than subcutaneous tissues may be detected, patients who simulated pain may be distinguished as a result of the determination of real pain regions and the identification of criminals and the reconstruction of crime scenes may be realized even during the night using surveillance cameras that integrate IR-imaging. Moreover, the evidence that cannot be currently identified may be detected via the dissemination of IR usage in laboratories in the future.

The most important development of IR-based technologies expected in the future will involve the usage of passive IR imaging. Depending on the use of this technology, humans and objects at crime scenes may be easily detected using the heat traces of humans and objects even if they are not present at the crime scene during the crime scene investigation.

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