A survey on Image Fusion for CWD

[1] Suhad Al-Shoukry
[1,] *Najaf Technical Institute, Al-Furat Al-Awsat Technical University (ATU),*
suhadalzhra2010@yahoo.com

Abstract
The proliferation of terror threats across the world has necessitated intense research on counter-terrorism measures and technologies. An urgent, growing need for developing and deploying highly efficient surveillance systems exists to provide safety and security to the public and its assets. Therefore, in this paper an intensive survey for the CWD, which will be more feasible for researchers on weapon detection system and image fusion world.

Keywords: *IR, Imaging sensors, Image fusion*

1. Introduction

Early terror threat detection has been identified as the most crucial step in preventing majority of dangerous and life-threatening situations posed by terrorists, and such emergencies can be mitigated by deploying accurate, efficient, and reliable surveillance systems [1].

Modern surveillance systems have advanced considerably; most systems are equipped with multiple cameras, allowing for effective detection, monitoring, and identification of people and objects [2]. As a precautionary measure, general public screening has been used in most outdoor environments with high human and vehicular traffic (e.g., airports, railways, metro stations, bus stations, military checkpoints, sports arenas, educational campuses, stadiums, theatres, and shopping malls) and often carried out either manually or using detection gates [3].

Despite the considerable success of most surveillance screeners, traditional screeners are occasionally ineffective; firearms, ceramic knives, guns, and inflammable explosives have gone undetected by traditional scanners, allowing attackers to pass through detection gates, resulting in terrorist attacks in public facilities or hostage situations for perpetrating their evil catastrophic agenda [4].

Providing hope and addressing current and potential terror attacks is the paramount mission of any law enforcement team, who invests significant government funding to safeguard innocent lives from imminent threats [5]. The challenge for law enforcement agents involves early detection of weapons and explosives concealed under human clothing to neutralize imminent threats and prevent physical damage; consequently, increasing demand for security has motivated the scientific community to develop efficient imaging devices that are medically safe and produces high throughput [6]. An automatic threat recognition system that can detect concealed weapons should be designed [7].

Imaging sensors are devices capable of detecting or measuring physical properties from an environment [8]. These small devices provide precise information on chosen features targeted by a system. These sensors are integrated with various intelligent systems, allowing them to interact with one another without human intervention [9]. Currently, image sensing mechanisms feature few variants, including thermal or infrared, microwave, millimeter waves, terahertz, and visual-based systems. Multi-camera systems present a wide range of optics, which are integral and crucial to detection systems [10]. Good optics provides enhanced image and video quality. Optics with low noise input coupled with a dynamic range are considered the best for surveillance systems [11].

Multi-sensor fusion is a technique that combines data obtained from different sensors and integrates the data at various levels. Multi-sensor fusion techniques are utilized in remote sensing, robotics, monitoring equipment as well as transportation and biomedical devices [12].

Health hazard caused by most imaging scanners for screening people and target objects have been raised by researchers; the radiation type emitted by these systems can cause cancer and other health-related issues [13]. By and large, the scientific community believes that frequent exposure to x-ray radiation can exert a carcinogenic effect on human body [14]. Hence, only harmless imaging devices should be utilized for screening when detecting hidden objects.

2. Literature Review

Visible light cameras (VLC) employ sensors capable of communication and embedded with tiny VLC hardware [15]. These VLC receivers use photo-sensitive systems or a camera system for light sensing [16]. These receivers extract data with the aid of light beams [17]. Infrared (IR) cameras, such as long-wavelength IR (LWIR) cameras, generate images on the basis of slight temperature variations [18]. Images produced by IR cameras are possibly slow or may vary because of the temperature ranges required by different applications. IR sensors should consider the dynamic range along with temperature variations to produce optimal results [19]. The ever-present threat of terrorism subjects the public to enhanced screening systems using full body scanners; these scanners have raised concerns over privacy invasion [20]. Microwave frequencies have been effective for detecting concealed objects; the problem is whenever projecting 2D magnitude images, scanners using microwave frequencies reveal the body image in full graphic detail causing embarrassment and privacy concerns [21].

In combination with computer vision algorithms, various cooperative signal processing techniques have been proposed as a ground-breaking technology for immediate detection of concealed weapons performed by simply scanning at a distance [22]. Owing to extensive research and ongoing development of imaging devices coupled with multispectral band systems, these devices have become popular surveillance screening systems. Exploring multispectral bands has invariably led to safe imaging scanners for screening people to prevent possible terrorist attacks [23]. The rapid digitization of semiconductor technology has paved the way for superior performing miniature digital imaging sensors [24]. These imaging sensors can be easily interfaced with modern consumer electronics for capturing images exploring the specific electromagnetic spectrum to provide a uniform image output [19]. The mechanism for obtaining an image involves substantial internal processing. When the light source strikes the sensor, an electrical charge is stored in the sensors, which are then converted to digital information using digital signal processing techniques, such as quantization and filtering, or other interpolation algorithms. The encoded data is subsequently stored in memory and further decoded to generate an analogue image signal [25]. In Figure 1, illustrates the schema of a digital camera for capturing visual images.

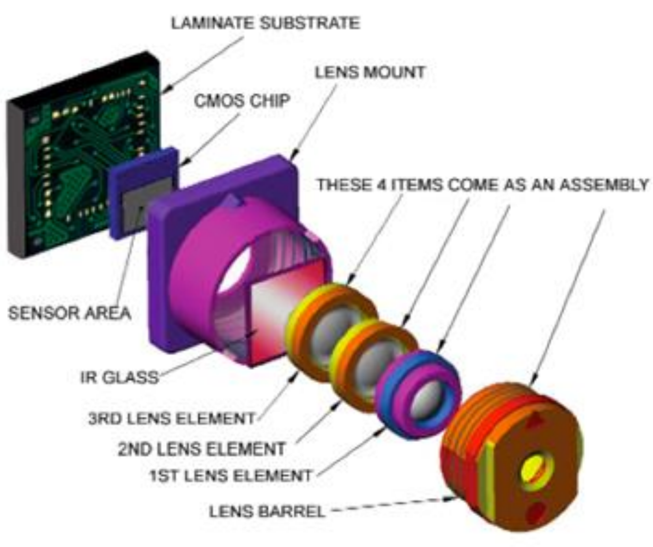

Figure 1. Schema for visual-image sensing camera [26]

Thermal infrared imaging is commonly used in military night vision, target detection, and surveillance applications [27], as shown in Figure 2. It is often referred to as infrared thermography because it allows electronic equipment to detect thermal energy for checking energy patterns and temperature variations [28]. When a subject of interest is exposed to infrared radiation, temperature variations can be detected from the surface of the subject [29]. More thermal energy is emitted from a hot object than a cold one [30]. The same working principle of a digital camera is applied to a thermal imaging camera; the input signal is scanned and detected and passed through an analogue-to-digital converter (ADC) for encoding in the digital imaging processor and finally reconverted to an analogue signal using a digital-to-analogue converter as shown in figure 3 [31]. Such imaging device taps thermal energy; thus, an external cooler is also incorporated in the equipment [32].

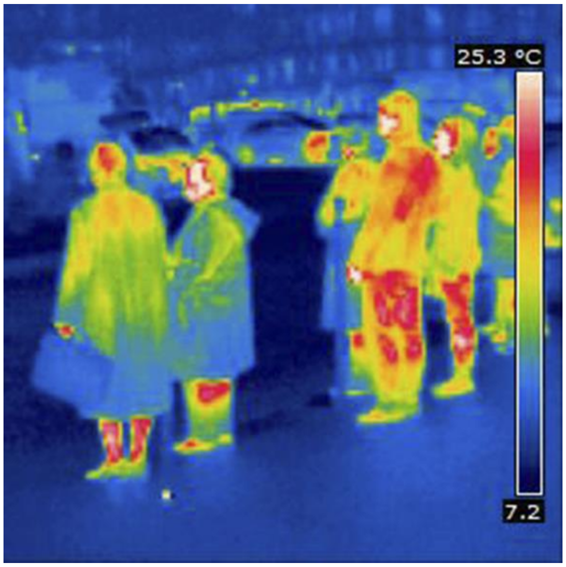

Figure 2. Thermal infrared imaging

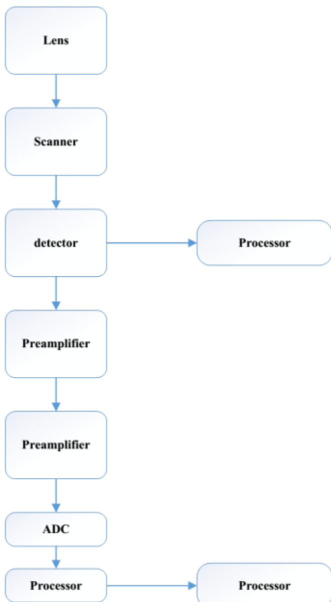

Figure 3. The process of imaging sensor camera for thermal infrared.

Recently, research and development in the fields of security and surveillance have been confirmed beneficial in generating major boost and backing of government agencies for providing innovative automatic solutions to promptly diffuse the dangers posed by global terrorism today [33]. The problem escalated after the aerial attacks on the World Trade Center on September 11, 2001. Progress has been persistent since the inception of the first weapons detection program in 1995 with the backing of the National Institute of Justice [34]. The American Air Force Research Laboratory had administered and funded the research project to deploy automatic concealed weapons detection systems [35]. Technological advances in digital signal processing, computer vision, and machine learning algorithms have been preferred by researchers and the scientific community to develop state-of-the-art image scanning devices [36]. The National Institute of Justice has been instrumental in directing the development from the scientific community by releasing guidelines for the technologies used in concealed weapon detection [37]. Prior policy implementations have also tapped the expansive imaging sensors technology and extensively explored computer vision image processing algorithms.

The advantages and disadvantages of different imaging systems have been succinctly published [38]. The guidelines issued by the National Institute of Justice in 2001 provide a comprehensive summary of imaging sensors, highlighting their different aspects, such as illumination, vicinity, transferability, and manageability. Analysis of image-processing tools for efficiently detecting weapons concealed under fabric has not only exposed flaws in a few algorithms but also provides alternatives to effectively overcome such defects [39]. The feasibility of using x-rays, terahertz, and passive millimeter-wave imaging techniques to effectually detect concealed weapons by penetrating through fabric was successfully demonstrated with X-ray systems, but they necessarily involve harmful ionization radiations that can cause damage to the human body with overexposure [40]. As a result of the perceived harm and public outcry, attention was diverted to passive millimeter-wave imaging techniques [41].

Millimeter waves are high-frequency electromagnetic waves that can detect apparent temperature variation through the energy reflected or emitted by the source. Owing to the alarming rise in global terrorism and growing demand for safe security scanners, passive millimeter-wave imaging devices have been confirmed to provide effective threat-detection systems because they can efficiently detect concealed weapons under various weather conditions and at any time by penetrating effortlessly through clothing or foliage [42]. Despite the numerous advantages of millimeter-wave systems, providing low-cost and high-quality millimeter wave (MMV) images is not economically sustainable using the cylindrical aperture hardware system -which shown in figure 4. Terahertz imaging radiation is potentially harmless, and it can penetrate through fabric and other materials to detect dangerous hidden objects. It also finds multitude end-user applications in spectroscopy and imaging. The terahertz imaging spectrum enjoys the most inimitable signature of electromagnetic waves to identify objects made of different materials. Nonetheless, physical hardware devices are extremely costly and are unfeasible for commercial use [43]. Consequently, researchers unanimously consider passive millimeter-wave and infrared-wave imaging as the most fitting technology for security and military purposes in terms of cost, safety, and non-intrusive nature. Different objects are visible, owing to variations in intensity values. This difference in infrared data can be attributed to temperature variations.

Assimilating complementary, incomplete, and inconsistent information data from multiple imaging sensors to create a subsequently complete single image has been the core principle of image fusion [44]. To produce tailor-made solutions for specific applications, the new image is subjected to further ample image-augmentation techniques available in image processing. Decades of research on image processing paved the way for ground-breaking landmark innovations, such as x-ray and magnetic resonance imaging scanners that have changed the face of medical diagnosis. Image fusion is widely researched in biomedical engineering, military and defense, remote sensing, robotics, computer vision, and many other fields [45].

Hence, preceding proposals discussed the following processes: image registration, filtering input images, de-noising complementary images, applying transforms (e.g., discrete wavelet, and Laplacian pyramid), image data reduction and compression, images fused in multiple ways (maximum fusion rule and pixel-averaging rule), along with image segmentation, edge detection, data clustering as well as feature selection and extraction. All these processes were eventually considered for identifying and detecting concealed weapons. Previous works emphasized the different aspects of image processing, such as image enhancement, image compression, and optimization. Consequent efforts were channeled toward combining different algorithms for concealed weapon detection. Prior research outcomes indicate that the increase in the development of new hybrid approaches can overcome the pitfalls of previous implementations. In Figure 4 , shows the CWD with person holding a weapon.

Figure 4. Weapon concealed underneath the rightmost

A. Pre-Processing

Before an image or video sequence is presented to a human observer for operator-assisted weapon detection or inputted into an automatic weapon detection algorithm, pre-processing the images or video data is advisable to maximize their analysis [46]. The pre-processing steps considered in this section include enhancement and filtering for the removal of shadows, wrinkles, and other artifacts [47]. When more than one sensor is used, pre-processing must also include registration and fusion procedures.

B. MMW Image Denoising and Enhancement

Numerous techniques have been developed to improve the quality of MMW images. This section describes a technique for simultaneous noise suppression and object enhancement of passive MMW video data and presents experimental results [48].

Denoising video sequences can be achieved temporally or spatially [49]. Temporal denoising involves motion-compensated filtering, in which the motion trajectory of each pixel is estimated and then a 1D filtering along the trajectory is conducted [50]. This step reduces the blurring effect that often occurs when temporal filtering is performed without regard to object motion between frames. The motion trajectory of a pixel is also estimated using various algorithms such as optical flow methods, block-based methods, and output Bayesian methods. However, if the motion in the image sequence is not abrupt, then the search for motion trajectory can be restricted to a small region in subsequent frames. Image fusion involves the extraction of information acquired in several domains as shown in figure 5.

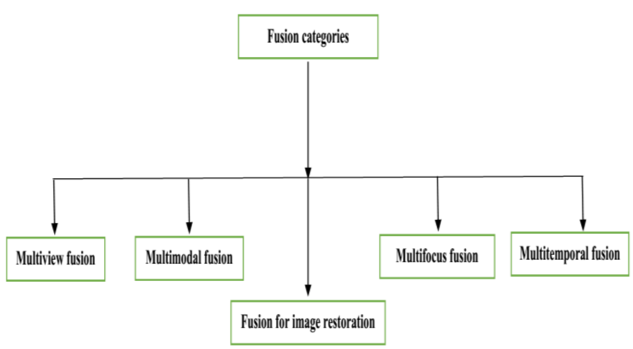

Figure 5. Image fusion classification

3. Discussion

It is very important to neutralize the threat situation immediately to prevent any physical damage. With this motivation general public screening either manually or with the Walk-through detection gates have been used at places with high people traffic such as airports, railways, metro, bus stations, military checkpoints, sports arenas, educational campuses, stadiums, theatres, shopping malls etc.

However, there have been instances where firearms and explosives have gone undetected by traditional scanners and walk through portals resulting in catastrophic damage. Often Ceramic knives, Ceramic guns, inflammable explosives cannot be detected which can potentially be used by terrorists to blow up public facility or to hold people at ransom to further their agenda. Despite the huge success of these Screeners it is not always an optimal and safe solution for a quick screening of a large crowd of people to walk through the portal one by one to detect concealed person borne threat. It is not only time consuming but also can raise a false alarm.

Hence the need of the hour is to design an automatic threat recognition system that can detect concealed weapons. Off late the most popular Signal processing in conjecture with Computer Vision algorithms have been employed as ground-breaking technology to enable concealed weapon detection instantly by simply scanning from a standoff distance. Due to the extensive research and rapid ongoing development of imaging devices coupled with multispectral band systems have garnered huge popularity as surveillance screening systems[51],[52]. Exploring Spectral bands have led to the development of safe imaging scanners for screening people to prevent possible terrorist attacks.

Currently there are few variants of image sensing mechanisms namely thermal or infrared, micro wave, millimeter wave, terahertz and visual. Increasing demand for security has motivated scientific community to develop imaging devices that are not only efficient and produce high throughput but also are medically safe and ethical[53],[54].

Research community have argued that some of the scanners used for screening are potentially hazardous as they have a type of radiation that can cause cancer and other health related issues. By and large scientific community is of the belief that frequent exposure to x-ray radiation can have carcinogenic effect on human body hence it is advisable to use only harmless imaging devices for screening to detect hidden objects[55].

Table 1. The most related work finding and future development

Author	Finding	Possible development
[56]	Their results shown a feasible contrast stretching was able to solve the overexposed and under-exposed image issues	Future development using detection methods like applying artificial neural networks, and extreme machine learning
[57]	A good method based on double-density dual tree complex wavelet transform (DDDTCWT)	Contrast based on image segmentation using fusion method can be proposed
[58]	They employed a modern filter based on homomorphic filter, entropy of blocks and blending approach for image fusion	homomorphic filter can be developed in different ways to increase the efficiency
[59]	They proposed am applied image fusion algorithm based on discrete wavelet transform to detect a concealed weapon under a person's clothing	Their method can be developing fir the concealed weapon hidden under clothes or in bags without a human present
[37]	They prototype device for concealed weapon detection using two cameras: IR and visual	It cloud be developed by adding supervised LDA to get different experiments on different images

4. Conclusion

Many related works had the efforts to draw attention to combining visual and infrared imaging for concealed weapons detection. Computer-vision algorithms called image-fusion algorithms have garnered widespread popularity. Image fusion involves combining two images obtained from multiple sensors to provide more accurate complete information that is suitable for human perception and comprehension. Context enhancement of the combined image helps with pattern matching and identifying concealed firearm for human visual perception.

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