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DWT Based Image Fusion for Concealed Weapon Detection

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ABSTRACT: In this paper, the technology which predicts the suicide bombers and explosion of weapons through imaging for concealed weapon detection is described. The detection of weapons concealed under a person's cloth is an obstacle to the improvement of the security of the general public as well as the safety of public assets like railway station and airports. It is desirable to detect concealed weapons and explosive material from a standoff distance, especially when it is impossible to arrange the flow of people through a controlled process. The goal is the development of technology of automatic detection of concealed weapons. So fusion algorithm is proposed for early and automatic detection of weapon. Image fusion is a process of combining two or more images into an image. It can extract features from source images, and provide more information than one image. The feasibility of the proposed fusion technique is demonstrated by some experimental results.

Key Words: Concealed weapon detection (CWD), Milli meter wave Image (MMW Image), Image Fusion, Wavelet Transform**.**

I. INTRODUCTION

Concealed weapon detection (CWD) has been necessary as the concern about public safety increases. The public transportation system and gathering places attracted most of the interests from the terrorists because of its economic significance and the influence that the terrorists can exert through it. The introduction of computed tomography based on x-ray to the airport check in procedure for the passenger luggage has improved the security. Security check still relies on the hand held and portal-style metal detectors assisted by human stop and search. There are drawbacks for this type of detectors, and the weaknesses can be exploited by the terrorists. The public and authority call for complex and comprehensive security systems. A variety of approaches to concealed objects detection on the human body based on magnetic, acoustic or ultrasound, electromagnetic resonances based target recognition, and image processing technologies have been developed. In the image processing technology, image is acquired by the THz, infrared, x-ray or millimeter wave imaging system. Image fusion has been identified as a key technology to achieve improved CWD procedures. Image fusion is a process of combining complementary information from multiple sensor images to generate a single image that contains a more accurate description of the scene than any of the individual images [1-3]. The objective of image fusion is to combine information from multiple images of the same scene. The result of image fusion is a new image which is more suitable for human and machine perception or further image processing tasks such as segmentation, feature extraction and object recognition [4]. Multiresolution analysis plays an important role in image processing, it provides a technique to decompose an image and extract information [5].

II. LITERATURE REVIEW AND RELATED WORK

A numbers of technologies are being developed for Concealed Weapon Detection (CWD). Paulter *et al.,* proposed Concealed Weapons and Contraband Imaging and Detection [6]. Nelson *et al.,* proposed Metal Detection and Classification Technologies. In this paper they proposed the Basic pulse induction metal detection scheme for concealed weapon detection [7]. Achanta *et al.,* proposed Non-linear Acoustic Concealed Weapons Detections. Their operating principle is dependent on the acoustic reflectivity of the object. It is worth noting that acoustic waves are mechanical vibrations, the reflectivity is related to the shape, orientation and hardness of the object. Basically, hard objects produce high acoustic reflectivity, plastic objects could provide the same strength of reflectivity as metals, which differs from EM wave based technologies. However, there is a problem of the penetration ability of clothes for ultrasonic detection when it is used for CWD operation, for example, leather could cause large acoustic reflections which make the concealed weapons undetectable.

Also, there is no differentiation in the reflections from weapons and hard non weapon objects. A nonlinear acoustic CWD detection by combining ultrasonic and acoustic methods has been suggested [8].

Baum, in 1971 proposed on the singularity expansion method for the solution of electromagnetic interaction problem. This method is named as singularity expansion method (SEM), it is based on the analytic properties of the electromagnetic response as a function of two sided Laplace transform variables which can be called the complex frequency. The singularity expansion method (SEM) is stimulated by observing the transient electromagnetic response which appears to be dominated by a few damped sinusoids. The extracted target signature (characterized by the extracted complex natural resonance frequencies) is compared to the database that stored signatures of the all the known weapons to determine whether there is a match. If yes, an alarm is automatically activated [9].

Mohamed Mansoor Roomi *et al.,* proposed a Detection of Concealed weapons in X-ray Images using Fuzzy K-NN. They provide an automatic method for detecting concealed weapons, typically a gun in the baggage by employing image segmentation method to extract the objects of interest from the image followed by applying feature extraction methods namely Shape context descriptor and Zernike moments. Finally the objects are classified using fuzzy K-NN as illicit or non-illicit object [10]. Xiaodong Zhuge *et al.,* proposed A Sparse Aperture MIMO-SAR-Based UWB Imaging System for Concealed Weapon Detection. They have proposed a novel imaging system for CWD by combining the advantages of SAR, MIMO technology, and large operational bandwidth from the resolution requirements for CWD [11]. Sheeja Agustin *et al.,* proposed an Image segmentation of concealed object by terahertz imaging. Multilevel thresholding method is applied to get initial segmentation of concealed objects in terahertz images. Then Gonzalez method and Gonzalez Improved methods are proposed to detect and segment concealed objects in terahertz images more correctly with specific shape [12].

Xilin Shen *et al.,* proposed a Detection and Segmentation of Concealed Objects in Terahertz Images. Terahertz imaging makes it possible to acquire images of objects concealed underneath clothing by measuring the radiometric temperatures of different objects on a human subject [13]. Bhavna Khajone *et al.,* proposed a Concealed Weapon Detection Using Image Processing [14]. Zhiyun Xue proposed a novel scheme for concealed weapon detection using colour image fusion [15]. Xu *et al.,* proposed a new image algorithm combining Projection onto Convex Sets algorithm (POCS) and nonlinear extrapolation algorithm for improving millimetre wave images [16].

Timofey Savelyev *et al.,* describe two approaches to short-range microwave imaging by means of ultra-wideband (UWB) technology. The first approach deal with synthetic aperture radar (SAR) that employs transmit-receive antenna pair on mechanical scanner. The second one represents a multiple input multiple output (MIMO) antenna array that scans electronically in the horizontal plane and mechanically, installed on the scanner, in the vertical plane. The mechanical scanning in only one direction reduces significantly the measurement time [17].

Hua-Mei Chen *et al.,* proposed Imaging for Concealed Weapon Detection [18]. D. Novak proposed a new scheme for concealed weapon detection. They proposed a new electromagnetic (EM) solution for concealed weapons detection at a distance. Their proposed approach exploits the fact that the weapons of interest for detection, whether they are a hand gun, knife, box cutter, etc, each have a unique set of EM characteristics. The particular novelty of their technical solution for concealed weapons detection at a distance lies in the use of millimeter wave signals over a wide frequency band (26–40GHz or Ka-band) to excite natural resonances in the weapon and create a unique spectral signature that can be used to characterize the object [19].

III. IMAGING SENSORS

Imaging sensors are as follows :

A. THz Imager

Teraview is the first commercialized terahertz imaging system using a short pulse as the waveform. Two methods can be used to generate THz based on electronics and photonics. For the photonic method, the femto-second laser TDS systems are very popular [20]. THz can be generated by mixing of two laser frequencies in a photo conducting antenna. Systems of this kind are compact and less expensive than femto second laser systems [21]. The electronic approach is to use electronic component such as Schottky-barrier diode (SBD), super- conductor-insulator-superconductor (SIS) and hot electron bolometre (HEB) mixers as the heterodyne detectors [22]. One disadvantage of using the electronic approach to generate THz signals is the limited output power which is not suitable for standoff detection. Since metals, ceramic guns and knives, clothes and human skin gives different level of reflection in the THz band, THz pulsed imager can be used for security screening. THz based CWD has the advantages of high resolution, wide THz spectra, and uses non ionizing radiation to illuminate human body. The system is transportable, both metals and non-metals can be detected. While THz provides high resolution, it has the drawbacks of high atmospheric absorption and is limited to operation close to the target.

B. Infrared Imager

The operating principle of an infrared imager is based on the detection of thermal radiation difference from the target space. Infrared detection of concealed weapons or dangerous contraband materials is essentially a function of the temperature difference between the object and the human body. Infrared imaging has a few drawbacks when used for CWD operations. Firstly, the wavelengths in infrared band are too short to penetrate clothes. Assuming the clothing is tight, the radiation from the human body heats the clothes and the radiation is reemitted which would make the target image blurred. For loosely wearing clothes, it would be even more difficult for CWD operation as the human body radiation would be spread over large area. Secondly, when the temperature of the concealed target approaches that of the human body, which is likely to occur when the target is concealed in the body for a long time, detection would be difficult. Infrared technology based imagers are passive and transportable and portable. Stand-off operation is possible. Both metals and non-metals can be detected. But it has the drawbacks of low penetration ability to clothing and no differentiation (assuming emissivity is the same) for targets with the same temperature.

C. X-ray Imager

The first commercially viable CT scanner was invented by Sir Godfrey Hounsfield in Hayes, United Kingdom at EMI Central Research Laboratories using x-rays. Hounsfield conceived his idea in 1967. The theory of operation for x-rays imager can be explained by the Compton Effect [6]. X-ray imager is an active system. The system is generally large in size but transportable and it is close range detection. Both metals and non-metals can be detected. It has the advantages of high resolution, high penetration ability. Scanning speed of commercially available x-ray imagers is high enough, a few seconds per scan. The drawbacks of the x-ray imaging for a human body are that it contains anatomical information of human body, it raises the privacy issue. There may be a safety concern because x-ray radiation is ionizing, even though the dosage is much below the level that the authority believes is safe, public acceptance is thus an issue.

D. Millimeter wave imagers

Millimeter wave imagers can be categorized into four types which are as follows:

1. MMW Radar Imager.
2. Broadband or Noise Pulse MMW imager.
3. Microwave Holography imager.
4. Passive MMW imager.

Imaging systems operating at 27-33 GHz (microwave holographic imager) [23], 94 GHz (passive imager) [24]. Recently a sensor working at 220 GHz based on state of the art solid state components has been demonstrated for passive MMW imaging [25] and showed acceptable image quality for standoff detection of metallic and non-metallic objects. It is believed that for operating frequency above 500 GHz, only active systems are effective for standoff concealed target detection due to the atmospheric and material attenuation [26]. The mechanism of active imaging is based on the reflectivity contrast from different materials in the target space. Passive imaging mechanism is more complex, for frequency less than 100 GHz, it is produced by the contrast in emissivity and reflectivity from the different target materials, for frequencies at 500 GHz and above, it is dominated by the emissivity of the items and their physical temperature [24].

Resolutions of MMW imagers are generally high enough for weapons detection. Both metallic and non-metallic targets can be detected. Penetration to clothing is good. Standoff detection can be achieved. The MMW imager can be a portal style system. Handheld MMW imager is also possible. MMW imagers pose no ionizing hazard to the individuals. MMW technology is imaging based, discriminating objects by their images. Compared to signature based identification and classification, imaging based technology requires a large amount of target information, which makes the system complex and costly.

Table 1. Comparison of various imaging sensors.

Imaging sensors	**Penetration**	**Proxi-mity**	**Drawback**
THz	medium	Near	1. Standoff detection unsuitable 2. high absorption loss
Infrared	Low	Far	1. Low penetration 2. No diffentiation when temperature contrast is low
X-ray	High	Near	1. Privacy violation 2. safety concerns
MMW	High	Far	high cost

IV. IMAGE FUSION USED FOR CWD

In the present scenario, the safety is the prime concern. So the Fusion algorithm is proposed for early and automatic detection of weapon. In this technique, Image Fusion algorithm based on discrete wavelet transform is used. The wavelet transform decomposes the image into low-high, high-low, high-high spatial frequency bands at different scales and the low-low band at the coarsest scale. The L-L band contains the average image information whereas the other bands contain directional information due to spatial orientation. Higher absolute values of wavelet coefficients in the high bands correspond to salient features such as edges or lines. With these premises, Hui Li *et al.*, [27] propose a selection based rule to perform image fusion in the wavelet transform domain. Since larger absolute transform coefficients correspond to sharper brightness changes, a good integration rule is to select, at every point in the transform domain, the coefficients whose absolute values are higher.

A. Wavelet Transforms for Images

The images are a two dimensional function. In two dimension, a two-dimensional scaling function, $\varphi(x,y)$, and three two-dimensional wavelets, $\psi^H(x,y)$, $\psi^V(x,y)$, and $\psi^D(x,y)$, are required [28]. Each is the product of a one-dimensional scaling function φ and corresponding wavelet ψ. Excluding products that produce one-dimensional result, like $\varphi(x)\psi(x)$, the four remaining products produce the separable scaling function

$$\varphi(x,y) = \varphi(x)\,\varphi(y) \quad (1)$$

and separable, "directionally sensitive" wavelets

$$\psi^H(x,y) = \psi(x)\,\varphi(y) \quad (2)$$

$$\psi^V(x,y) = \varphi(x)\,\psi(y) \quad (3)$$

$$\psi^D(x,y) = \psi(x)\,\psi(y). \quad (4)$$

These wavelets measure functional variations– intensity or gray-level variation for image – along different directions: ψ^H measure variations along columns (for example, horizontal edges), ψ^V responds to variations along rows (like vertical edges), and ψ^D corresponds to variation along diagonals. The directional sensitivity is a natural consequence of the separability imposed by Eqs. (2) to (4); it does not increase the computational complexity of the two dimensional transform. Given separable two dimensional scaling and wavelets function, extension of the one dimensional DWT to two dimensions is straightforward. We first define the scaled and translated basis function:

$$\varphi_{j,m,n}(x,y) = 2^{j/2}\,\varphi(2^j x - m, 2^j y - n), \quad ...(5)$$

$$\psi^i_{j,m,n}(x,y) = 2^{j/2}\,\psi^i(2^j x - m, 2^j y - n), \quad ...(6)$$

Where index i identifies the directional wavelets in Eqs. (2) to (4). Rather than an exponent, t is a superscript that assumes the values H, V, and D. The discrete wavelets transforms of function f(x,y) of size M × N is then

$$W_\varphi(j_o,m,n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)\,\varphi_{j0,m,n}(x,y) \quad ...(7)$$

$$W^i_\psi(j,m,n) =$$

$$f(x,y) = \frac{1}{\sqrt{MN}} \sum_m \sum_n W\varphi(jo,m,n)\,\varphi j0,m,n(x,y) + \frac{1}{\sqrt{MN}} \sum_{i=H,V,D} \sum_{j=j0} \sum_m \sum_n Wi\psi\,(j,m,n$$

J_0 is an arbitrary starting scale and the $W_\varphi(j_0,m,n)$ coefficients define an approximation of f(x,y) at scale j_0. The $W^i_\psi(j,m,n)$ coefficient add horizontal, vertical, and diagonal details for scales $j \geq j_0$. We normaly let $j_0 = 0$ and select $N = M = 2^J$ so that j = 0,1,2,........,J-1 and m, n = 0,1,2,......,2^j -1. Given the W_φ and W^i_ψ of Eqs. (7) And (8), f(x,y) is obtained via the inverse wavelet transform [28]

V. METHODOLOGY USED

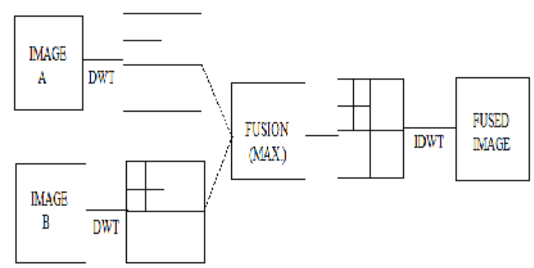


Fig.1. Wavelet fusion scheme.

The steps followed in methodology are as following:

1) The input MMW image is transformed from RGB colour space (R: red, G: green, B: blue) into HSV colour space (H: hue, S: saturation, V: brightness value). HSV colour space is used for the subsequent processing since it is well suited for interpretation.

2) Both the original MMW image and the reverse polarity of the MMW image are used. The motivation for doing this is that, the concealed weapon is sometimes more evident in the MMW image with reverse polarity.

3) Transform the original MMW image in to the reverse polarity of the MMW image and named as Complement MMW image.

4) Combined the original MMW image and the reverse polarity of the MMW image (Complement MMW image), which is named as combined image.

5) The discrete wavelet transform (DWT) is applied on the combined image to decompose the image into multiscal representation. After applying DWT, Combined image is decomposed into the approximation coefficient matrix (CA) and detail coefficient matrix CH, CV, CD. Where CH, CV, CD are horizontal coefficient matrix, vertical coefficient matrix and diagonal coefficient matrix respectively.

6) The discrete wavelet transform (DWT) is also applied on the HSV formatted image of MMW image to decompose the image in to multiscal representation. After applying DWT, the HSV formatted image is also decomposed in to the CA, CH, CV and CD.

7) In the fusion step, coefficient of both combined image and HSV formatted image of MMW image are used. Composite multiscale representation is constructed from the source representations and a fusion rule. The fusion rule we used is: choose the maximum value of the coefficients of the source images.

8) Finally the fused image is obtained by taking an Inverse DWT transform of the composite multiscale representation. This fused image is the final image which shows the concealed weapon.

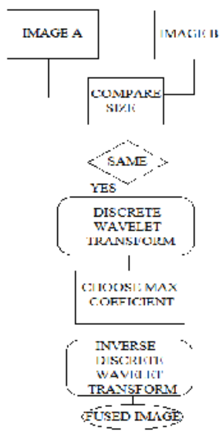
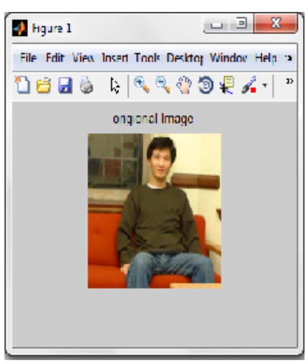
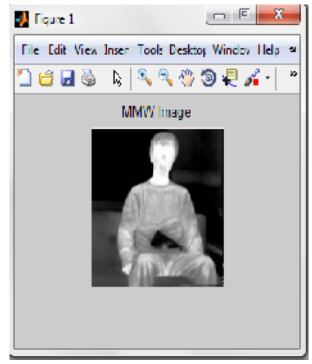
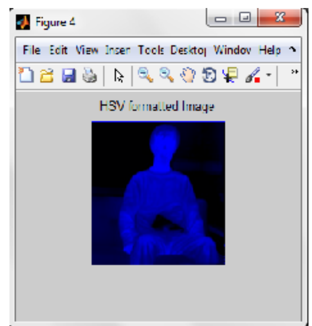


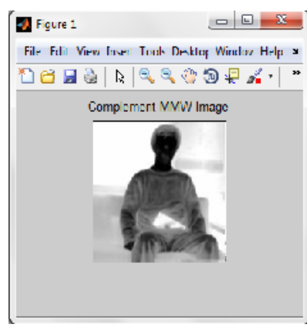
Fig.2. Flowchart used in Methodology.

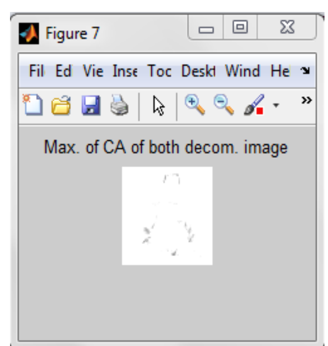
VI. EXPERIMENTAL RESULT











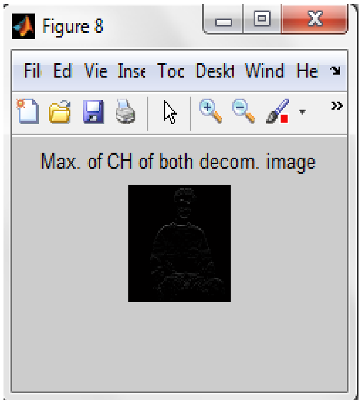


Figure 8
Max. of CH of both decom. image

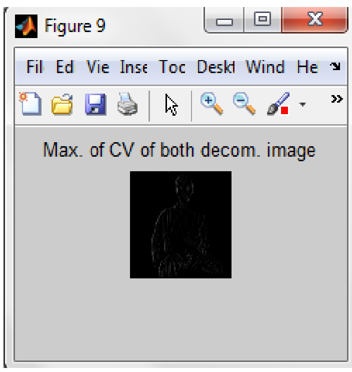


Figure 9
Max. of CV of both decom. image

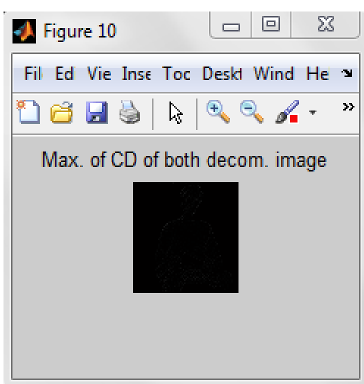


Figure 10
Max. of CD of both decom. image

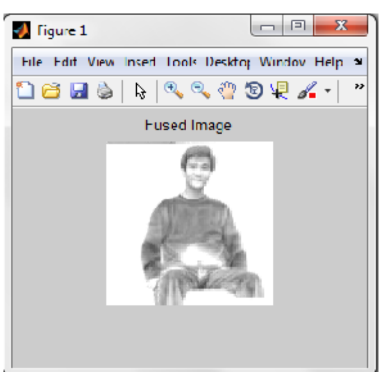


Figure 1
Fused Image

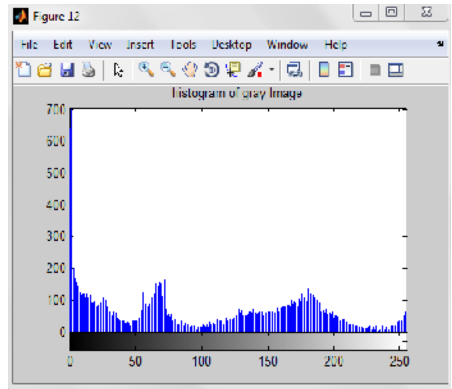


Figure 12
Histogram of gray Image
700
600
500
400
300
200
100
0
0 50 100 150 200 250

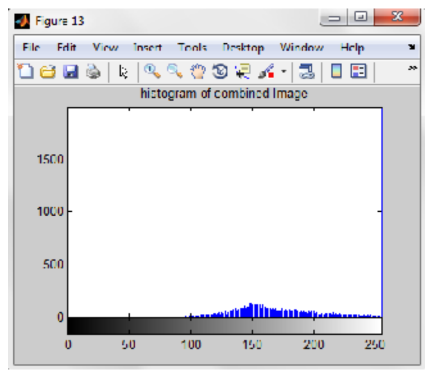
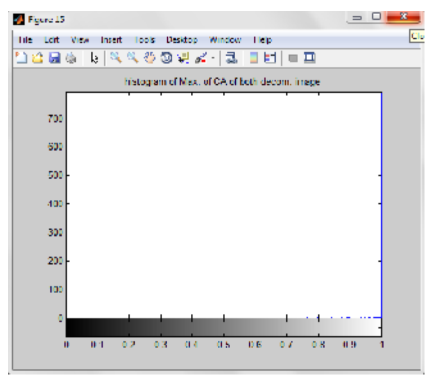
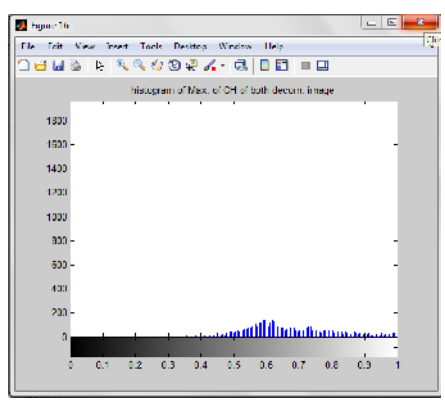
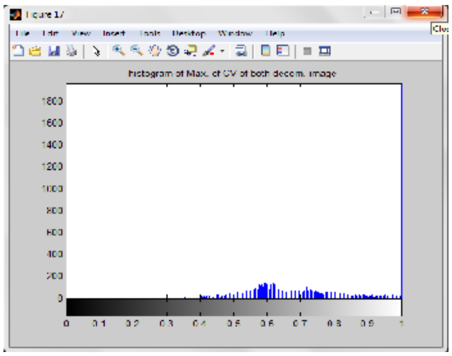
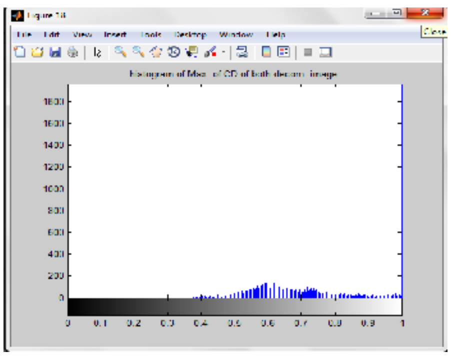


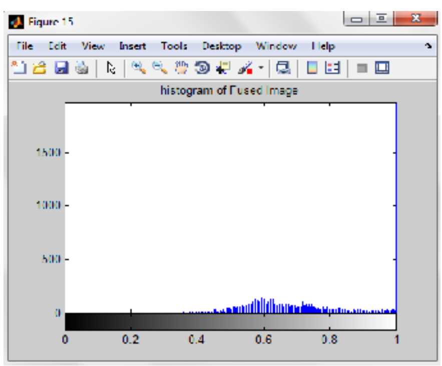
Figure 13
histogram of combined Image
1500
1000
500
0
0 50 100 150 200 250


histogram of Max. of CA of both decom. image


histogram of Max. of CH of both decom. image
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1







VII. CONCLUSION

Weapon Detection using Image Processing, involves manual screening procedures for detecting concealed weapons such as handguns, knives, and explosives are common in controlled access settings like railway station, airports, entrances to sensitive buildings, and public events. In this paper we have presented a new weapons detection system based on fusion algorithm. We applied image Fusion algorithm based on discrete wavelet transform to detect a concealed weapon under a person's clothing. We have confirmed through a theoretical investigation and experiment that the proposed technique can differentiate between a variety of weapons and non-threatening targets, as well as concealed weapons. The MMW sensor is very costly; it is limitation of this technology. The proposed algorithm can also be applied for detecting a concealed weapon hidden under clothes or in bags without a human present.

REFERENCES

[1]. Z. Liu, K. Tsukada, K. Hanasaki, Y.K. Ho, Y.P. Dai, "Image fusion by using steerable pyramid, Pattern Recognition" Lett. **22**, pp 929–939, 2001.

[2]. G. Piella, "A general framework for multiresolution image fusion: from pixels to regions" Report PNA-R0211, 31 May 2002.

[3]. P.J. Burt, R.J. Kolczynski, " Enhanced image capture through fusion", Proceedings of the *Fourth International Conference on Computer Vision*, Berlin, Germany, pp. 173–182, 1993,.

[4]. Gonzalo Pajares, Jesus Manuel de la Cruz "A wavelet Based image fusion" ELSEVIER, 2004.

[5]. C.Y. Wen, J.K., "Chen Multi-resolution image fusion technique and its application to forensic science" ELSEVIER, November 2003.

[6]. Paulter, N. G.; Guide to the Technologies of "Concealed Weapons and Contraband Imaging and Detection" National Institute of Justice Guide, pp 33-50, February 2001.

[7]. Nelson, C. V.; "Metal Detection and Classification Technologies" Johns Hopkins APL technical Digest, Vol. **24**, Number 1, 2004.

[8]. Achanta, A.; McKenna, M.; Heyman, J.; Rudd, K.; Hinders, M.; Costianes, "Non-linear Acoustic Concealed Weapons Detections" 34th Applied Imagery and Pattern Recognition Workshop (AIPR05), 2005.

[9]. Baum, C. E.; "on the singularity expansion method for the solution of electromagnetic interaction problem" Air Force Weapons Lab. Interaction Notes, Note **88**, Dec. 1971.

[10]. Dr. Mohamed Mansoor Roomi and R. Rajashankari, "Detection of concealed weapons in X-ray Images using Fuzzy K-NN", *International Journal of Computer Science, Engineering and Information Technology (IJCSEIT)*, Vol. **2**, No.2, April 2012.

[11]. Xiaodong Zhuge and Alexander G. Yarovoy, A Sparse Aperture MIMO-SAR-Based UWB Imaging System for Concealed Weapon Detection. *IEEE Transaction on goscience and remote sensing* vol. **49**, no. 1, January 2011.

[12]. Sheeja Agustin. A, S.S. Vinsley and Dr. N. Krishnan, "Image segmentation of concealed object by Terahertz imaging", *IEEE International Conference On Computational Intelligence and Computing Research, 2010*.

[13]. Xilin Shen, Charles Dietlein, "Detection and Segmentation of Concealed Object in Terahertz Images'', *IEEE Transaction on Image Processing*, 2007.

[14]. Bhavna Khajone, V. K. Shandilya, "Concealed Weapon Detection Using Image Processing", Iternational Journal of Scientific & Engineering Research, Volume 3, Issue6, June-2012.

[15]. Zhiyun Xue, Rick S. Blum, "Concealed Weapon Detection Using Color Image Fusion", ISIF 2003.

[16]. Z. Y Xu, W.B. Dou, Z. X. Cao,"A New Algorithm For Millimeter-Wave Imaging Processing", *IEEE- 2008.*

[17]. Timofey Savelyev, Xiaodong Zhuge, Bill Yang "Development of UWB Microwave Array Radar for Concealed Weapon Detection", *IEEE, 2010.*

[18]. Hua-Mei Chen, Seungsin Lee, Raghuveer M. Rao, Mohamed-Adel Slamani, and Pramod K. Varshney "Imaging For Concealed Weapon Detection" *IEEE Signal Processing Magazine*, March 2005.

[19]. D. Novak, R. Waterhouse and A. Farnham, "Millimetre wave Weapons Detection System", *Proceedings of the 34th Applied Imagery and Pattern Recognition Workshop (AIPR05), IEEE.*

[20]. Mochizuki, K.; Aoki, M.; Tripathi, S. R.; Hiromoto, N.; "Polarization-changeable THz time-domain spectroscopy system with a small incident-angle beam-splitter Infrared, Millimeter, and Terahertz Waves" IRMMW-THz 2009, 34th International Conference on, Page(s):1 – 2, 21- 25 Sept. 2009.

[21]. Kleine-Ostmann, T.; Knobloch, P.; Koch, M.; Hoffmann, S.; Hofmann, M.; Hein, G.; Pierz, K.; "Compact and cost-effective continuous wave THz imaging system Lasers and Electro-Optics" *IEEE*, Page(s): 405-406.Vol. **1**, 2002.

[22]. Gerecht, Eyal; "A Passive Heterodyne Hot Electron Bolometer Imager Operating at 850 GHz" IEEE, vol. 56, May 2008.

[23]. Sheen, D. M.; McMakin, D.L.; Hall, T. E.; "Three-dimensional millimetre wave imaging for concealed weapon detection Microwave Theory and Techniques", IEEE, Page(s):1581 – 1592, Sept. 2001.

[24]. Appleby, R.; Anderton, R.N.; "Millimeter Wave and Submillimeter Wave Imaging for Security and Surveillance *Proceedings", IEEE* Volume **95**, Page(s):1683-1690, 8 Aug 2007.

[25]. Stanko, S.; Notel, D.; Wahlen, A.; Huck, J.; Kloppel, F.; Sommer, R.; Hagelen, M.; Essen, H.; "Active and passive mm-wave imaging for concealed weapon detection and surveillance Infrared, Millimeter and Terahertz Waves", 2008.

[26]. Appleby, Roger; Bruce Wallace, H.; Standoff Detection of Weapons and Contraband in the 100 GHz to 1 THz region IEEE Transactions on antennas and propagation. Vol. **55**, No. 11, November, 2007.

[27]. Hui Li, B.S. Manjunath, Sanjit K. Mitra H. Li, B. S. Manjunath and S. K. Mitra, "Multisensor Image Fusion Using the Wavelet Transform" Proc. first international conference on image processing, ICIP 94, Austin, Texas, Vol. **I**, Pages 51-55, Nov1994.

[28]. Gonzalez, "Digital Image Processing," 2nd edition, pp. 386, 387.