International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-3, February 2013

A Novel Noise Removal Technique of X-Ray Carry-on Luggage for Detection of Contraband/Illicit Object(s)

Sajid Ullah Khan,Wang Yin Chai, Chai Soo See

Abstract: Luggage inspection systems play an important role in ensuring national security at airports. In this paper, a novel approach of noise removal from dual energy X-ray images is proposed to ensure the national security at airport. This novel approach is used as a key step in our previous framework to get perfect results. High Energy and Low Energy x-ray images are combined, de-noise it with the proposed novel approach and at the end enhance the fused image with histogram specification to improve the contrast. The final image did not only contains the details, but is also background-noise-free and contrast-enhanced, therefore easier to segment automatically or be interpreted by screeners, thus reducing the false alarm rate in X-ray luggage inspection. It is observed that the proposed approach is more suitable for screeners in detecting contraband/illicit objects than using other conventional techniques.

Keyword: dual Energy x-ray Image enhancement, image restoration, image fusion, De-noising, Histogram specification.

I. INTRODUCTION

Terrorist attacks have nowadays become a serious threat, and this threat only continues to grow. Attempts can be made to load weapons, explosives materials and Special Nuclear Materials (weapons-grade uranium and plutonium) onto an aircraft forthe purpose of transporting them to another destination in a concealed manner among personal baggage. Hand-searching of luggage and millions of travelers is impossible. Several methods exist for checking weapons, drugs and explosives at airports. More recent terror events such as 9/11 have further encouraged improvement of security in the aviation industry because of National security purposes. [1][2][3]. Advanced dual-energy X-ray luggage inspectionsystems are playing an important role in ensuringnational security at airports, court rooms, provincial and federalbuildings. These systems utilize X-rays of twodifferent energies. The high energy X-ray is generated with high voltage of 100 KV and the low energy X-ray is generated with a low voltage of 80 KV. When H.E X-rays penetrateobjects, the energy absorption depends primarily onthe material's density. The higher the density is, thehigher the energy absorption by the object, and hencethe darker the image.

Manuscript published on 30 February 2013.
***** Correspondence Author (s)
Sajid Ullah Khan, Faculty of Computer Science & Information Technology, University Malaysia Sarawak, Malaysia
Wang Yin Chai, Faculty of Computer Science & Information Technology, University Malaysia Sarawak, Malaysia
Chai Soo See, Faculty of Computer Science & Information Technology, University Malaysia Sarawak, Malaysia

For low-energy X-rays,however, the energy absorption depends primarily onthe effective atomic number of the material as well asthe thickness of the object.

Therefore, areas of highdensity materials such as metal are dark in both lowand high-energy X-ray images, but areas of lighterelements show as darker regions in low-energy imagescompared to high-energy images. As a result,lightelements in dynamites, for instance, (e.g., carbon,nitrogen and oxygen) can be detected by comparingthe low-energy X-ray image with the high-energy X-rayimage of the same scene [4].Commercial dual-energy X-ray luggage inspectionsystems feature dual-energy analysis to estimate theatomic number of materials in luggage. They fuse alow-energy X-ray image and a high-energy X-rayimage into a single image.The aim of dual energy x-ray image fusion is to integrate complementary information from the lowenergy x-ray image and the high-energy x-ray image such that the produced combined image is moreamenable for a successful screeners' interpretation [5].A limitation on conventionaltransmission X-ray imaging systems is theirincapability to differentiate between a thin sheet of astrong absorber and a thick slab of a weak absorber.This problem is usually solved in dual-energy X-raysystems by estimating the atomic number of material.

However, the accuracy of estimating the effectiveatomic number of materials in luggage is still to here false alarm rates are as high as 20% or more [4] and the images are still blurred and having low contrast/lost some of the details.

In effort to decrease the false alarm rate in dual energy X-ray systems and to increase the enhancement of the image, we employ an approach of fusion, de-noising and enhancement of images to make them more amenable for visual inspection as well as for post processing.

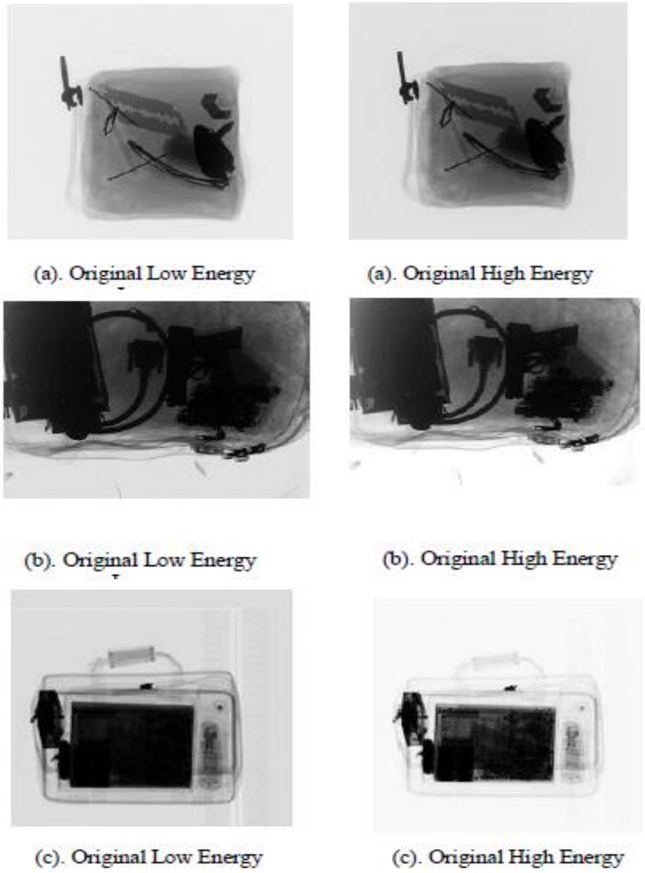
This paper is organized as follows. Section II presents the reasons/causes for spoiled dual energy X-ray images. Section III presents the related techniques and problems. Section IV presents our proposed novel approach, Section Vreports conclusion and finallySection VI contains references.

II. REASONS/CAUSES FOR SPOILED IMAGES

Dual energy X-ray system plays important role in airport security. It generates two types of images. i.e. High Energy and Low Energy X-ray image. Fig. 1 represents these images. Firstly, in dual energy X-ray system, X-rays penetrate object on low energy and high energy voltage and estimate the atomic number of material and discriminate between threats and non-threat object on the basis of their elemental composition.

*Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)*

As we know that most of explosive are organic in nature and most organic materials consist of the elements Hydrogen, Carbon, Nitrogen and Oxygen (H,C,N,O) with smaller amounts of heavier elements. Explosive are distinguished by relatively high proportions of N&O and relatively low proportions of C&H. On the other hand, illicit drugs are generally rich in H&C and poor in N&O [6]. Fig. 2 shows a stacked bar graph of the fraction of eachconstituent atom, as a percentage, for a selectionof explosives, illicit drugs and miscellaneousmaterials.



(Source of images: [12, 14])

Figure 1. Dual Energy X-ray luggage images

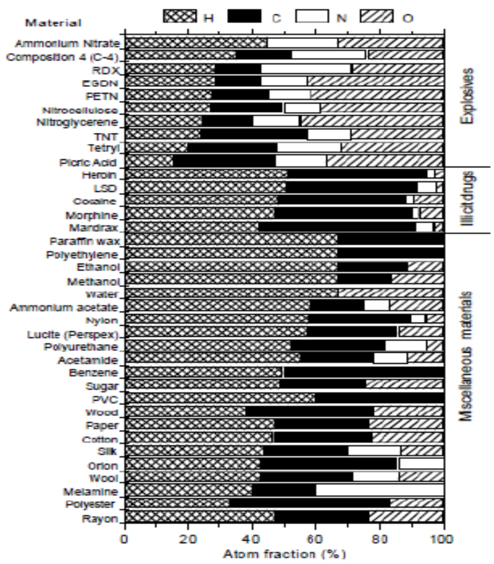


Figure 2. Atomic fractions (as a percentage) of the elements H, C, N and O, which constitute a selection of explosives, illicit drugs and miscellaneous common substances.

As we know that contraband/illicit objects are capsuled/sheeted by some thick material to prevent from aviation security because of the fact that sometimes it can't absorb the object well due to the Thickness and Density of the object, so we lost some of the details or information and leads to blurred and low contrast. This problem happened with all kind of dual energy X-ray images either there is threat or not. As screener is the last body to decide that weather the detected object is threat or non-threat. So that's why images need to be enhanced.

Secondly photons drops randomly on object/image like some starting rain drops falling on ground. In Fig. 3 and Fig 4, we can see that some area of object get more photons and some get less, so due to this dis-continuity and non-uniformity, the image become noisy as well as it become noisy due to the bag complexity, acquisition, transmission, conversion from photons to digital etc. So due to the following reasons, X-ray images needs to be enhanced so that the screener can easily detect contraband/illicit objects and decrease the false alarm rates. As we discuss that there is no difference between contraband images or non-threatened images.

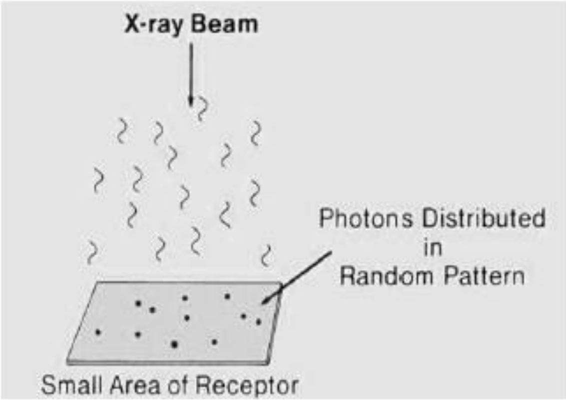


Figure 3.Photons drop randomly on object

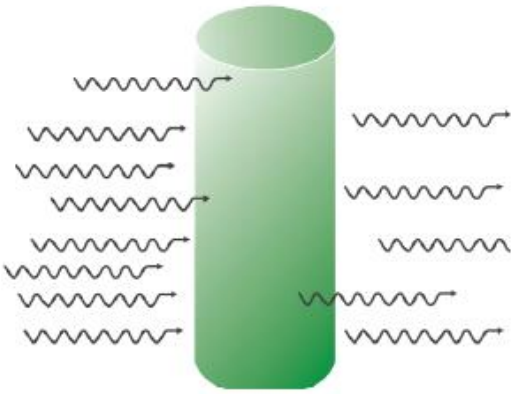


Figure. 4 X-ray attenuation. When an X-ray beam encounters an object, some of the X-rays will interact with the atoms in the object and lose all of their energy. As a result, fewer X-rays will make it out the other side of the object. So due to this less penetration X-images became noisy.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

III. TECHNIQUES USED FOR ENHANCEMENT AND ITS PROBLEMS

As we discuss in section II that the main problems in dual energy X-ray images are the noise (Background Noise) and the low contrast. Different researchers used different algorithms/techniques to overcome these problems but as discuss earlier that there is still false alarm rate of above than 20% and the screener feels difficulties in detecting contraband/Illicit objects.

In this paper, first we discuss the noise removal techniques and their drawbacks which are not suitable for removing noise from dual energy X-ray images and then we will discuss the methods of contrast enhancement.

The main filtering techniques use for noise removal are Mean and Median filter but now much more techniques are used for noise removing.

Mean filtering technique: it is used to remove noise [7]. Mean filter isuseful for removing grain noise from an image. The fundamental and the simplest of these algorithms is the Mean Filter. This filter is alsocalled as average filter. The drawback of Mean Filter is that it is poor in edgepreserving.

Median Filtering Technique: The Median filter is anon-linear digital filtering technique often used to remove noise. It provides better results than mean filtering techniques because it preserves edges.

But the drawback is that if we take a large window i.e. 5*5 or 7*7 then it leads to blurriness.

Others techniques used are Wiener filter technique, Gauss filtering, gradient weighting filtering, sequenceStatistical filtering, robust smoothing filtering, Crimmins noiseremoves filtering, edge preserved filtering and self-adaptive median filtering etc. [9]. Furthermore, Vector median filter, spatial median filter, Modified Spatial median Filter can also use but all these have its own drawbacks [10]. Some researcher's uses different framework for noise removing [10][11][12] but these techniques doesn't provide the best results.

All these techniques are used for different kind of noise removal i.e. some are used for Gaussian noise, some for impulse noise but in medical X-ray images, some for color images but as we are using dual energy X-ray images and the noise are due to the photons dropping randomly on object as show in Fig. 2 and due to the discontinuity, non-uniformity and bag complexity. The noise didn't affect the whole image but only some of the pixels so we can't use these methods/techniques directly for noise removal but we first detect the noise area and only remove noise from that area. Furthermore, whenever we remove noise, we must lose some of the details which are necessary for contraband detection for automatically inspection. Many of the researcher's uses Histogram Equalization techniques but its drawback is that it equalized the whole image not the interesting area only. Some uses gray level grouping but it has the drawback that it cannot enhance certain classes of low-contrast images very well, e.g., images with a noisy background [13]. Histogram stretching, contrast stretching techniques are also used but it has its own limitations.

VI. PROPOSED FRAMEWORK

A framework of combing High Energy and Low Energy x-ray images, de-noise it with a novel approach and at the end, enhance the fused image with histogram specification to improve the contrast. The flow charts of the proposed approach are presented in Fig. 5, 6. The novel approach is a key part of the framework consists of three main stages i.e. Image Fusion, de-noising and Image Enhancement.

In image fusion, high-energy image and low-energy image are combined into a single image tointegrate complementary information from thetwo images. There are three steps in this process.

VII. DISCRETE WAVELET DECOMPOSITION

In this stage, high-energy image and low-energyimage are combined into a single image to integratecomplementary information from the two images.Here we perform DWT on Lower energy and highenergy to obtain approximation coefficients and detail coefficients.A wavelet familyand a wavelet basis capable of representing imagedetails need to be selected. A practical selectionrule in imageprocessing applications is to use awavelet basis that can be presented enough detail variations, regardless of its wavelet family. Another issue to be determined is how many scalesare necessary for the decomposition. Too fewscales will cause the loss of too many details in thefused image, and too many scales will result in aroughfused image which is difficult for screenersto interpret. From literature review, it is proved that 4 scales generally yield wellresults.

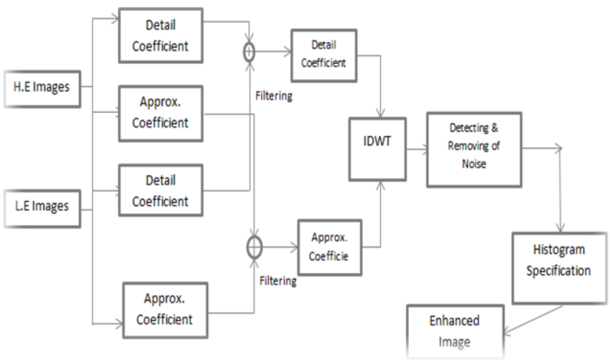


Figure 5. Proposed approach consists of image fusion, De-noising and enhancement steps.

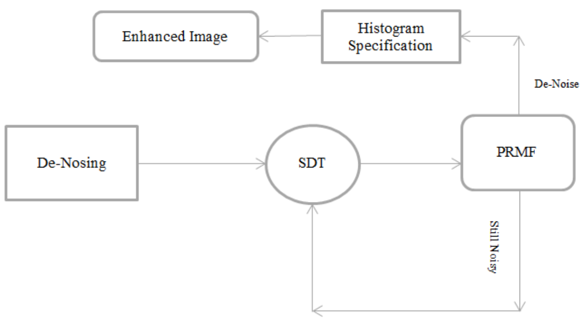


Figure 6. A Novel Approach of Image De-Noising

VIII. COEFFICIENT PROCESSING

Apply a low-pass filter to the approximation coefficients of *L* and *H*, respectively, to generatethe approximation coefficients of the fused image.The idea behind this step is that a smooth approximation of a given scene can make important features in the scene more easily discernible.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

We generate each of the approximation coefficients of the fused image, *F*, by averaging thecorresponding approximation coefficients of *L* and *H*, as given in Eq. 1.

$$w_{\varphi F}=1/2(w_{\varphi L}+W_{\varphi H}), \quad (1)$$

Where $w_{\varphi F}$, $W_{\varphi L}$ and $W_{\varphi H}$are the approximation coefficient of F, L and H, respectively.

Combining the corresponding detail coefficient of L and *H* to obtain the detail coefficients of the fused Image *F*. The objective of this step is toincorporate unique details from either *L* or *H* intothe fused image and also make details existing inboth images more prominent in the resulting image.We calculate thedetail coefficients at alldecomposition scales of the fused image bysumming the corresponding detail coefficients of *L*and *H* as given in Eq.2.

$$w_{\psi F}=(w_{\psi L}+W_{\psi H}), \quad (2)$$

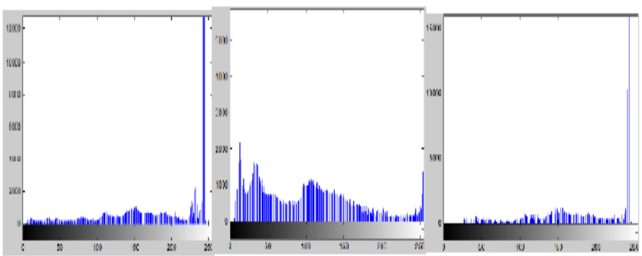
Where $w_{\psi F}$, $W_{\psi L}$ and $W_{\psi H}$are the detail coefficients of F, L and H, respectively.

IX. WAVELET RECONSTRUCTION

The fused image can be obtained by implementing IDWT using the approximation coefficients and detail coefficients from step 2. After Discrete Wavelet Transform, we get a good detail image contains the complementary information of both H.E and L.E images but the fused image is still noisy caused by photons randomly dropping and discontinuity and non-uniformity of the x-rays as well as image fusion has the disadvantage to produce some noise. Fig.7 shows that the fused image is still noisy, so we will reduced the noise from the fused image. Fig.8 shows the histogram of the fused images. Here for images (a) and (c), the histogram shows much brightness and for image (b), it show dark area. i.e. those images are not perfect and need enhancement.

(a) (b) (c)

Figure 7. After apply DWT to H.E and L.E images



(a) (b) (c)

Figure 8. Histogram of fused images

X. DE-NOISING FUSED IMAGE BY NOVEL APPROACH

Multi-sensor images generally have noisy backgrounds, such as seen in original X-ray images in Fig. 1. Although fused images generally reveal more detail information, but the background noise still exists in them, and is even amplified, making further processing and interpretation of these images difficult. Therefore, a De-noising operation is necessary to yield good enhancement and fusion result. The method of noise removing is described below.

As we know that like other images, all the pixels of X-ray images did not affected but only some of the pixels are effected due to the above said reasons. Fig. 9 represents the affected pixels. So first noisypixels of the corrupted image are identified using a spike detection technique (SDT). It is followed by a pixelrestoring median filter (PRMF) for recovering thosecorrupted pixels identified using SDT. The PRMFtechnique is very effective in noise removal. It uses a3X3-filtering window for noise filtering. Our technique ofSDT followed by PRMF is capable of producing highquality images and it prevents image blurring comparedto other de-noising techniques. It is also suitable for color images.

XI. NOISE DENSITY CALCULATION

Let I be the noisy image of size NXN of an object or scene captured by sensor. The noise boundaries of noisy image I are computed by spike detection technique. Let L1 and L2 be the lower and upper noise boundaries for the noisy image. The binary map (BM) of the noisy image is developed using the noise boundaries L1 and L2. If the image pixel 'y' lies within the noise boundaries, then it is uncorrupted and represented by a '0' in the binary map. The corrupted pixel is represented by a '1'in binary map.

$$BM = \begin{cases} \text{'0'} \text{ if } L_1 < y < L_2 \\ \text{'1'} \text{ if } y < L_1 \text{ or } y > L_2 \end{cases}$$

Compute the noise density ND of the noisy image.

$$ND = \frac{\text{sum of '1's in BM}}{N*N}$$

The value of ND ranges from 0 to 1.

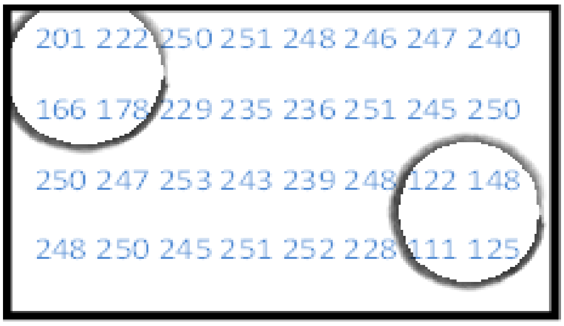


Figure 9. Represent effected pixels

XII. PIXEL RESTORATION MEDIAN FILTER

Image X and Binary Map of the image BM are inputs to the PRMF algorithm.

[1] Let pixel xij and corresponding bij are selected from image X and binary map BM respectively, where i=2…… (n-1) and j=2….. (n-1) for an image of size nxn. If bij= '0', then pixel xij is 'uncorrupted'. Hence go to step [5].

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

[2] Select a 3x3 window Wx in X and Wb in BM centered around (i,j)th pixel xij in X and bij in BM respectively.
[3] Check for '0's (uncorrupted pixels) in Wb and store corresponding elements of Wx in vector A.
[4] If A is a null vector go to step V. Else replace xij with median of vector A. xij= median (A). (5)
[5] Increment i, j and consider next xij, bij and go to step [2].

By using this algorithm iteratively along with updated binary map of the recovered image, noisefades from the noisy image.The entire steps involved in the filtering of a noisy image are given below.

Step I: Apply spike detection technique (SDT) and determine noise level I and noise level II (*NLI and NLII*).

Step II: Using *NLI* and *NLII* construct binary map *(BM)* of the corrupted image.
'0' stands for 'uncorrupted' pixels
'1' stands for 'corrupted' pixels

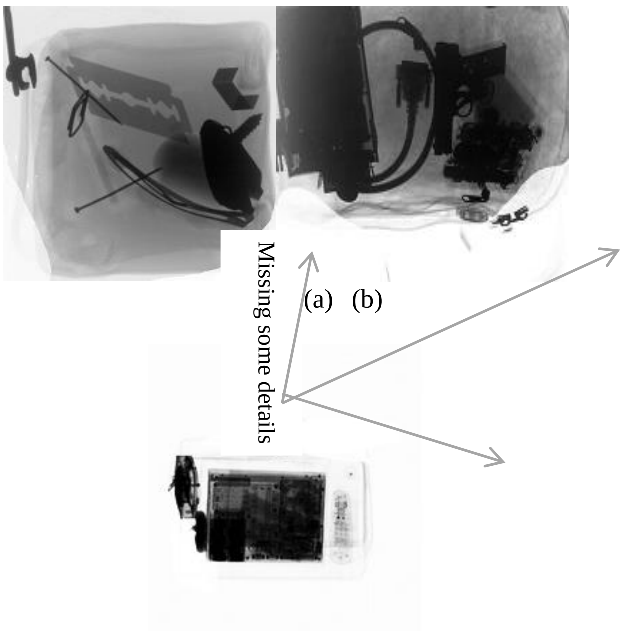
Step III: Apply Pixel Restoring Median Filter (PRMF) to the noisy image *X*
R = PRMF(X)

Step IV: New binary map (*NBM*) is simultaneously obtained by updating the old map value by '0' for the modified pixels.

Step V: If *NBM* has 'corrupted' pixels go to step III.

The steps (III-V) are repeated until the number of corrupted pixels in *NBM* reduces to zero.

After applying de-noising approach, we can see in Fig. 10 that much of the noise has been removed from the fused image but we lost little bit details. So at the end we will enhance the image especially the interesting area by histogram specification technique.



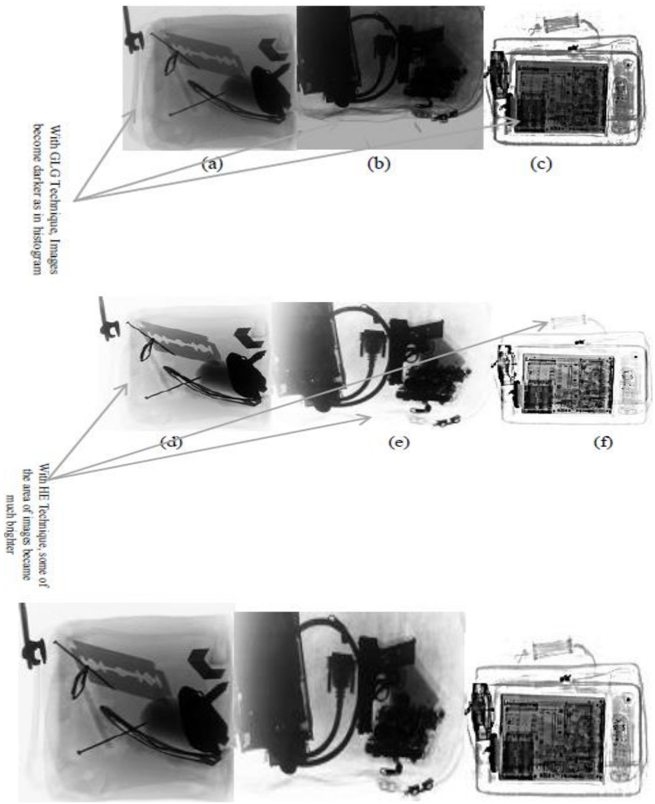
(c)

Figure 10. DWT + De-noising technique images

XIII. HISTOGRAM SPECIFICATION

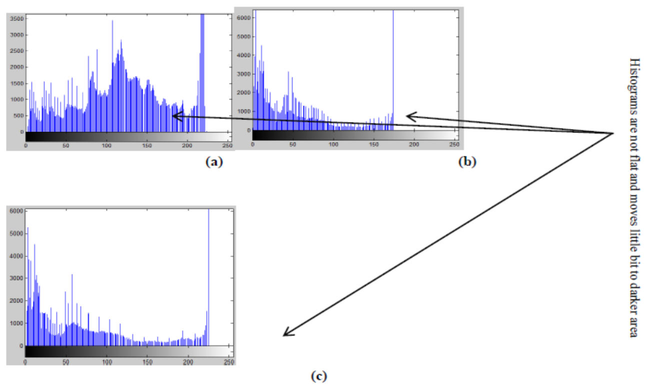
Histogram equalization enhances the whole image. It equalized the image but reduce the gray level. So we will use histogram specification technique to enhance the image especially the interesting regions. Here first equalized the original image then find out transformation function G (z) from the target histogram that is specified. At the end, apply inverse transform of the equalized image using G^{-1}. After applying Histogram specification, the resulting image contains more complementary information, noise free contain more complementary information, noise free and having more contrast. In Fig. 11, the result of proposed approach are compared with others conventional techniques. Visual inspection and the histogram in Fig. 12 clearly show that the result of proposed approach is better than the conventional techniques.

We compared the proposed technique with others conventional technique and we see that results from our proposed novel approach are better than the conventional techniques.



(a) (b) (c)

Figure 11. (a, b, c) De-noising result of Wavelet and GLG, (d, e, f) result of Wavelet and HE, (g, h, i) better images (result of proposed framework)



Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

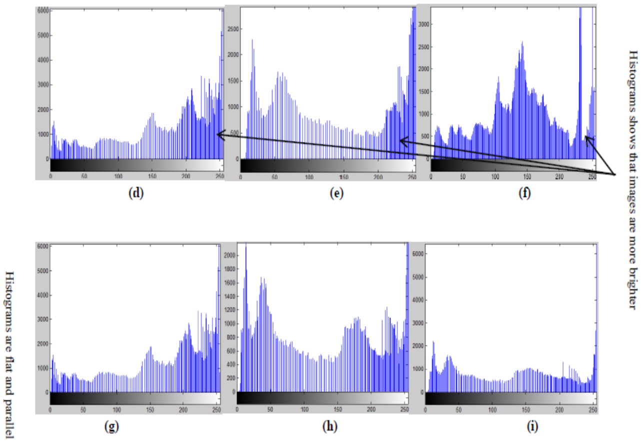


Figure 12. (a, b, c) Histogram of GLG, (d, e, f) Histogram of HE, (g, h, i) Histogram of Proposed Approach.

Visual inspection and Histogram of the proposed approach clearly show that the proposed approach is better than the conventional techniques. Histograms are more flat of the resulting images. Images have more details and this method/approach can improve the image definition efficiently.

XIV. CONCLUSION

We have developed a new combinational scheme to fuse, de-noise and enhance dual energy X-ray images for the detection of contraband/Illicit objects. In the framework, first DWT method is used to fuse dual energy X-ray images to integratecomplementary information from both H.E and L.E images.This fused image is then process by the novel approach of de-noising and finally enhanced by Histogram specification technique. The resulting final images contain complementary information from both sourceimages, and are background-noise-free and contrastenhanced.This approach can effectivelyimprove resultsof post segmentation algorithms and screeners' abilityto classify objects and interpret X-ray imagessuccessfully; therefore effectively reduce the falsealarm rates in X-ray luggage inspection.

Usually the enhancement image quality is measured based on visual observation however, inorder to compare the proposed approach more efficiently,

Indexes of contrast incrementand image definition will be adopted in our future work. Further we can use statistical techniques like Standard Deviation and Variance to measure the quality of the images obtained from the proposed approach.

REFERENCES

[1] Gozani, "The role of neutron based inspection techniques in the post 9/11/ 01 era",Volume 213, January 2004, Pages 460–463

[2] A. Buffler a, J. Tickner b, "Detecting contraband using neutrons: Challenges and future directions", Volume 45, Issue 10, December 2010, Pages 1186–1192

[3] George Zentai, "X-ray imaging for homeland security", Int. J. Signal and Imaging Systems Engineering, Vol. 3, No. 1, 2010

[4] S. Singh and M. Singh, "Review Explosives Detection Systems (EDS) for Aviation Security" Signal Processing, vol. 83, pp. 31-55, 2003

[5] Alexey Guilarte Noa and Edel B, Image Processing Methods for X-Ray Luggage Images: A Survey, Oct, 2011.

[6] Andy Buffler, "Contraband detection by fast neutron scattering",2nd National Nuclear Technology Conference, May 13–15, NAC, South Africa (2001)

[7] Pawan Patidar, Manoj Gupta,"Image De-noising by Various Filters for Different Noise", International Journal of Computer Applications (0975 – 8887) Volume 9– No.4, November 2010

[8] James C. Church, Yixin Chen, and Stephen V. Rice Department of Computer and Information Science, University of Mississippi, "A Spatial Median Filter for Noise Removal in Digital Images", IEEE, page(s): 618-623, 2008.

[9] Kenneth.R. Castleman, Translated by ZHU zhigang etc.1998.DIGITAL IMAGE PROCESSING [M].Beijing: Electronic and Industrial Press

[10] J.Harikiran, B.Saichandana, B.Divakar, "Impulse Noise Removal in Digital Images", International Journal of Computer Applications (0975 – 8887) Volume 10– No.8, November 2010

[11] M. Jaya Manmadha Rao, Dr.K.V.V.S.Reddy, "Image Fusion Algorithm for Impulse NoiseReduction in Digital Images", Global Journal of Computer Science and TechnologyVolume 11 Issue 12 Version 1.0 July 2011

[12] Zhiyu Chen; Yue Zheng; Abidi, B.R.; Page, D.L.; Abidi, M.A.; , "A Combinational Approach to the Fusion, De-noising and Enhancement of Dual-Energy X-Ray Luggage Images," Computer Vision and Pattern Recognition - Workshops, 2005. CVPR Workshops. IEEE Computer Society Conference on, vol., no., pp.2, 25-25 June 2005 doi: 10.1109/CVPR.2005.386

[13] ZhiYu Chen; Abidi, B.R.; Page, D.L.; Abidi, M.A.; "Gray-level grouping (GLG): an automatic method for optimized image contrast enhancement - part II: the variations," Image Processing, IEEE Transactions on, vol.15, no.8, pp.2303-2314, Aug.2006 doi: 10.1109/TIP.2006.875201

[14]. X-ray images, Department of Computer Science Engineering Universidad.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)