An Image Enhancement Technique of X-Ray Carry-on Luggage for Detection of Contraband/Illicit Object(s)

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Abstract
Luggage inspection systems play an important role in ensuring national security at airports. In this research, an effort of a new enhancement algorithm of dual-energy X-ray carry-on luggage images is proposed to ensure the national security at airports. A new approach of combing High Energy and Low Energy x-ray images, de-noise it 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 for the 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 inspection systems are playing an important role in ensuring national security at airports, court rooms, provincial and federal buildings. These systems utilize X-rays of two different 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 penetrate objects, the energy absorption depends primarily on the material's density. The higher the density is, the higher the energy absorption by the object, and hence the darker the image. For low-energy X-rays, however, the energy absorption depends primarily on the effective atomic number of the material as well as the thickness of the object. Therefore, areas of high density materials such as metal are dark in both low and high-energy X-ray images, but areas of lighter elements show as darker regions in low-energy images compared to high-energy images. As a result, light elements in dynamites, for instance, (e.g., carbon, nitrogen and oxygen) can be detected by comparing the low-energy X-ray image with the high-energy X-ray image of the same scene [4]. Commercial dual-energy X-ray luggage inspection systems feature dual-energy analysis to estimate the atomic number of materials in luggage. They fuse a low-energy X-ray image and a high-energy X-ray image into a single image. The aim of dual energy x-ray image fusion is to integrate complementary information from the low energy x-ray image and the high-energy x-ray image such that the produced combined image is more amenable for a successful screeners' interpretation [5]. A limitation on conventional transmission X-ray imaging systems is their incapability to differentiate between a thin sheet of a strong absorber and a thick slab of a weak absorber. This problem is usually solved in dual-energy X-ray systems by estimating the atomic number of material.

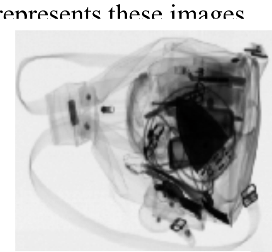
However, the accuracy of estimating the effective atomic number of materials in luggage is still to here false alarm rates are as high as 20% or more [4] and the images are still blurred and having low contrast/lost some of the details.

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.

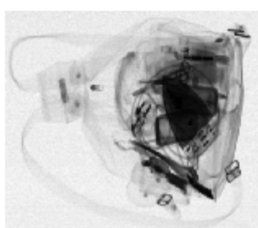
This paper is organized as follows. Section II presents the reasons/causes for spoiled dual energy X-ray images. Section III presents the related techniques and problems. Section IV presents our proposed approach, Section V reports conclusion and finally Section VI contains references.

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



Original H.E X-ray Image



Original L.E X-ray Image

Original H.E X-ray Image

Original L.E X-ray Image

(Source of images: [12])

Figure 1. Dual Energy X-ray luggage 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. 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]. 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. 2, 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.

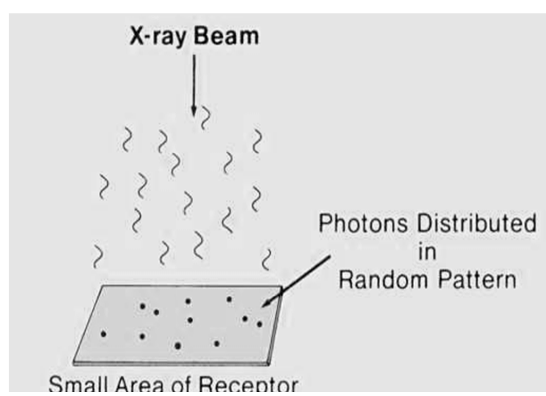


Figure 2. Photons drops randomly on object

The system only detects contraband/illicit objects and at the end, the screener will decide that the alarm is positive or not.

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 is useful for removing grain noise from an image. The fundamental and the simplest of these algorithms is the Mean Filter. This filter is also called as average filter. The drawback of Mean Filter is that it is poor in edge preserving.

Median Filtering Technique: The Median filter is a non-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, sequence Statistical filtering, robust smoothing filtering, Crimmins noise removes 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.

IV. PROPOSED FRAMEWORK

A new approach of combing High Energy and Low Energy x-ray images, de-noise it and at the end, enhance the fused image with histogram specification to improve the contrast. A new flow chart of the proposed approach is presented in Fig. 3. Proposed approach 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 to integrate complementary information from the two images. There are three steps in this process.

DISCRETE WAVELET DECOMPOSITION

In this stage, high-energy image and low-energy image are combined into a single image to integrate complementary information from the two images. Here we perform DWT on Lower energy and high

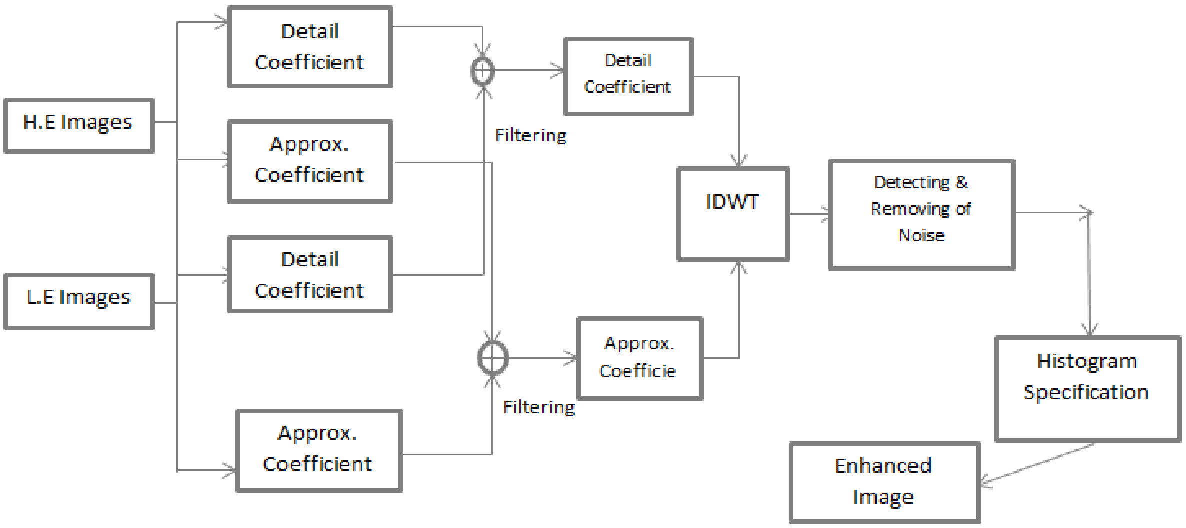


Figure 3. Proposed approach consists of image fusion, De-noising and enhancement steps.

to obtain approximation coefficients and detail coefficients. A wavelet family and a wavelet basis capable of representing image details need to be selected. A practical selection rule in image processing applications is to use a wavelet basis that can be presented enough detail variations, regardless of its wavelet family. Another issue to be determined is how many scales are necessary for the decomposition. Too few scales will cause the loss of too many details in the fused image, and too many scales will result in a rough fused image which is difficult for screeners to interpret. From literature review, it is proved that 4 scales generally yield good results.

COEFFICIENT PROCESSING

Apply a low-pass filter to the approximation coefficients of *L* and *H*, respectively, to generate the 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.

We generate each of the approximation coefficients of the fused image, *F*, by averaging the corresponding 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 to incorporate unique details from either *L* or *H* into the fused image and also make details existing in both images more prominent in the resulting image. We calculate the detail coefficients at all decomposition scales of the fused image by summing 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.

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.

Fig. 4 shows that the fused image is still noisy, so we will reduced the noise from the fused image.

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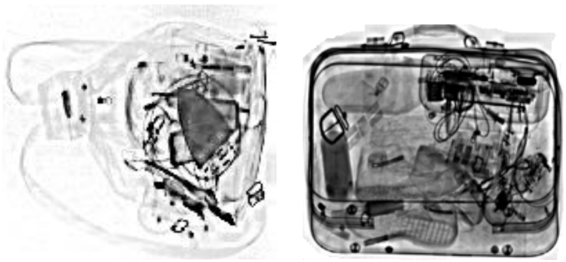


Figure 4. After apply DWT to H.E and L.E images

DE-NOISING FUSED IMAGE

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.

First noisy pixels of the corrupted image are identified using a spike detection technique (SDT). It is followed by a pixel restoring median filter (PRMF) for recovering those corrupted pixels identified using SDT. The PRMF technique is very effective in noise removal. It uses a 3X3-filtering window for noise filtering. Our technique of SDT followed by PRMF is capable of producing high quality images and it prevents image blurring compared to other de-noising techniques. It is also suitable for color images.

SPIKE DETECTION TECHNIQUE

The spike detection technique is applied to the corrupted image to determine the upper and lower impulse noise levels (*NL I and NL II)* in the corrupted image. The binary map of the corrupted image is constructed using these upper and lower noise levels. If an image pixel is falling inside these two boundaries, then it is considered as 'uncorrupted' and '0' is assigned to the binary map in the corresponding position of the considered image pixel. If the pixel considered is in the noisy range then it is considered as 'corrupted' and '1' is assigned to the binary map in the corresponding position.

PIXEL RESTORATION MEDIAN FILTER (PRMF)

The pixel restoring median filter is a robust technique. It is highly effective in noise removal and is superior compared to adaptive median techniques. The PRMF technique uses a 3X3-filtering window for removing the impulse noise. This makes PRMF algorithmically simple and can be used for obtaining higher quality images.

At the end, a noise fading technique is applied to recover the image.

NOISE FADING TECHNIQUE

The entire steps involved in the filtering of a noisy image is 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 method, we can see in Fig. 5 that much of the noise has been removed from the fused image. At the end we will enhance the image especially the interesting area by histogram specification technique.

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. Fig. 6 represents the resulting images.

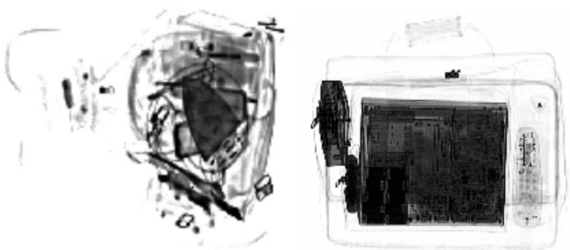
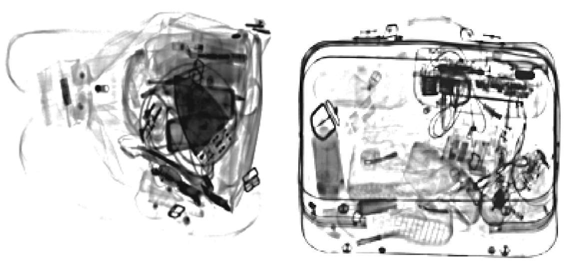
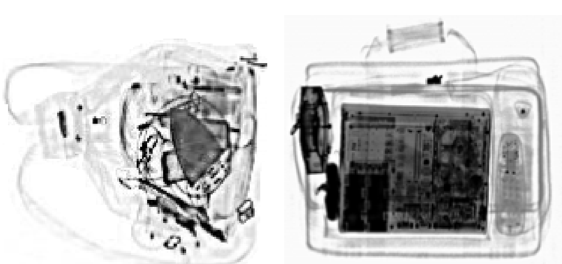


Figure 5. DWT + De-Nosing technique images

(a) **(b)**



(c) **(d)**



(e) **(f)**

Figure 6. (a, b) De-noising result of Wavelet and GLG, **(c, d)** result of Wavelet and HE, **(e, f)** better images (result of proposed framework)

From the resulting image, it is clearly determine that this image is more enhanced and have more details and this method/approach can improve the image definition efficiently.

V. 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. The proposed approach first uses a DWT method to fuse dual energy X-ray images to integrate complementary information from both H.E and L.E images. This fused image is then process by De-noising technique and final enhanced by Histogram specification technique. The resulting final image contains complementary information from both source images, and is background-noise-free and contrast enhanced. This approach can effectively improve results of post segmentation algorithms and screeners' ability to classify objects and interpret X-ray images successfully; therefore effectively reduce the false alarm rates in X-ray luggage inspection.

Usually the enhancement image quality is measured based on visual observation however, in order to compare the proposed approach more efficiently, Indexes of **contrast increment** and **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.

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