# Image Enhancement by Image Fusion for Crime Investigation

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**Abstract**

In the criminal investigation field, images are the principal forms for investigation and for probing crime detection. The imaging science applied in criminal investigation is face detection, surveillance camera imaging, and crime scene analysis. Digital imaging succors image manipulation, alteration and enhancement techniques. The traditional methodologies enhance the given image by improving the local or global components of the image. It proves a debacle since it engages noise amplification, block discontinuities, colour mismatch, edge distortion and checkerboard effects thereby limiting image processing tasks. To the same degree of enhancement, spurned artefacts are given rise. Thus to balance the global and local factors of the image and to weed out the tenebrous components; fusion of multiple alike images are performed to produce a meliorated image. The fusion is done by fusing a pyramid constructed image and a wavelet transformed image. The pyramid image and the wavelet transformed image are then fused through to afford a revealing image for better perception by the human visual system. The experimental results show that our proposed fusion scheme is effective and the fusion is applied over a surveillance camera image grab.

**Keywords:** Image Fusion, Image Enhancement, Image Pyramids, Wavelet Transformation, Image Blending.

## 1. INTRODUCTION

In any organization a record of the activities are maintained in the form of books, databases, registers, surveillance to incline with an able management of the organization. These records help trace and track any of the investigation within the organization during occasions of crime. The various data recorded in any organization are entry and exit registers for persons entering the organization along with their vehicular data, surveillance cameras to record clippings of the activities surrounding any of the public spaces around the organization. The police make use of the cameras installed by organizations to investigate any crime related activities if any takes place in the areas surrounding the organization. It is demanded for any organization to have a complete camera log of all the activities as it may assist during any critical activities to be investigated by any governmental agencies.

The advancement in imaging and video technologies has paved the direction for better image processing technologies and image enhancement methodologies. The interest in images has grown globally since many people require higher quality and resolution. Imaging science as a study has assisted robot vision, satellite imagery and medical imaging. This has resulted in image processing becoming a specialized field of study. Since the advent of digital imaging the image enhancement along with detail manipulation has been on the stands.

Image enhancement for lucubrated versions of the image is in need. To cement this, a contrast enhancement by fusion of pyramid and wavelet transformed images is proposed.

It can be observed from the traditional methodologies of image enhancement that it does seek noise amplification, block discontinuities, colour mismatch, edge distortion and checkerboard effects thereby limiting image processing tasks. To surmount these effects, fusion of images was developed. Fusion improves the contrast of the image and provides a realistic image compared to other image enhancement techniques.

## 2. IMAGE ENHANCEMENT

Image enhancement abets in anatomization of an image for exposing information. Image enhancement entails into detail optimization, pixel comprehensibility and feature perceptibility.

### 2.1 Histogram Methods

An image histogram [1-2] is a type of histogram that acts as a graphical representation of the tonal distribution in a digital image. It is a representation of the number of pixels in an image as a function of their intensity. It plots the number of pixels for each tonal value. Each pixel is a single sample that carries only intensity information where intensity is a measure of the wavelength-weighted power emitted by a light source.

Histogram methods equalize the image attempting to make the histogram of an input image as uniform as possible, and thus increases the dynamic ranges of low contrast images adaptively.

Adaptive histogram equalization (AHE) is used to improve contrast in images. It differs from ordinary histogram equalization in the respect that the adaptive method computes several histograms, each corresponding to a distinct section of the image, and uses them to redistribute the lightness values of the image. It is therefore suitable for improving the local contrast of an image and bringing out more detail. However, AHE has a tendency to over amplify noise in relatively homogeneous regions of an image. A variant of adaptive histogram equalization called contrast limited adaptive histogram equalization (CLAHE) prevents this by limiting the amplification.

Histogram methods recede in various ways as the contrast of the image is varied in accordance to local components of the image. Thus pixels are heightened in certain areas and not balanced globally.

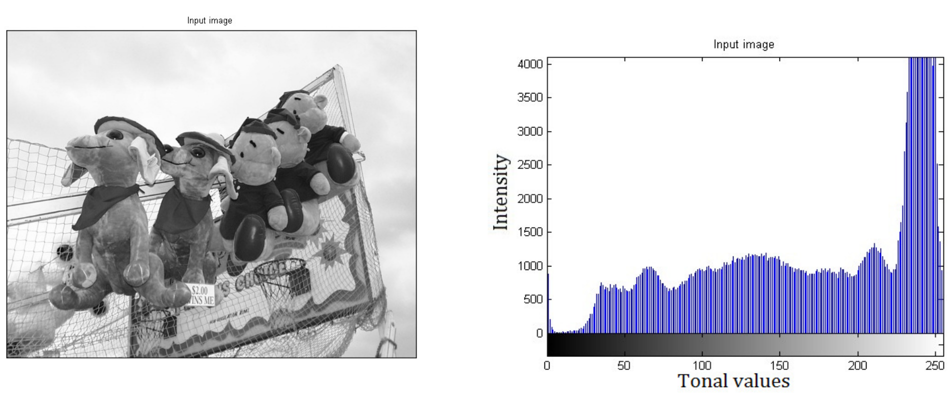


**FIGURE 1:** A sample test image and its histogram.

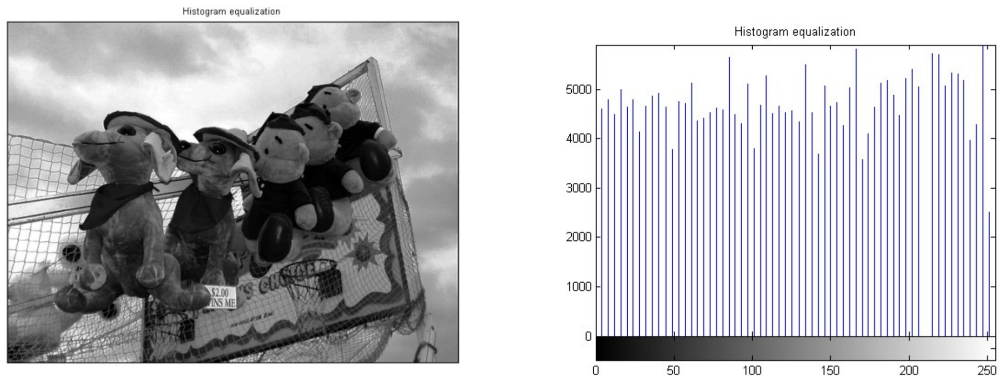


**FIGURE 2:** Histogram equalization applied over the sample image and the equalized histogram.

### 2.2 Image Equilibrating

Images can be balanced by averaging its pixels, normalizing its pixels or stretching its pixels.

Averaging is done by taking an average of the neighborhood pixels of the image. Then the pixel values are modified and are thus enhanced.

Normalizing method takes the nearby round values to its neighborhood pixels. Then the pixels stay enhanced.

Stretching of an image involves the process of adding a value to a pixel to make it heavier so that the image pixels are equally spread.

The methods of image equilibrating morph the pixel values in each case thereby they are manipulated and played with pixel values.

Since these methods do not use any standard filtered pre-set values the images are tampered with.

### 2.3 Image Fusion

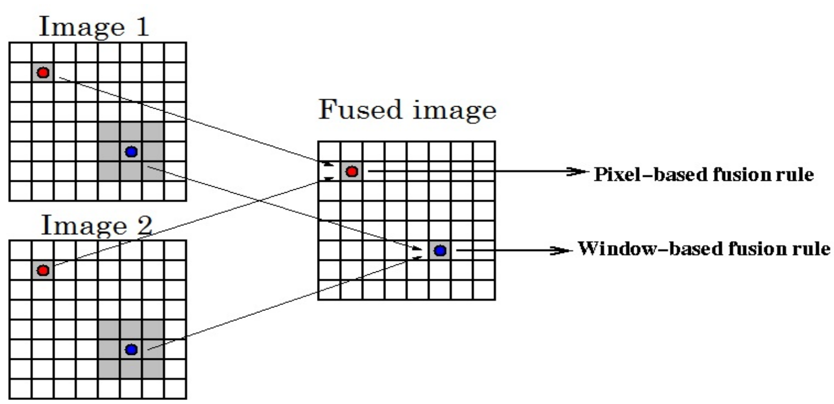


**FIGURE 3:** Image Fusion Operations.

Image fusion [1] can be done by spatial domain fusion and/or transform domain fusion. Spatial domain techniques are performed to the image plane itself and they are based on direct manipulation of pixels in an image. While Transform domain technique is a mathematical procedure done on the image to convert it from one domain to another (frequency), in the transformed domain, the image could be more easily handled for operations such as compression, denoising, sharpening, etc. that require cutting of the high-pass frequency components. The original image can be constructed by inverse transform function.

In the figure 3, a basic spatial fusion is done by fusing the pixels I1(Xi,Yi) and I2(Xi,Yi). Spatial fusion can be done by fusing a pixel or a sliding window based pixel.

In pixel fusion, each pixel of the image is fused. In a sliding window, each pixel is calculated by its neighborhood and a modified pixel is fused for each pixel value.

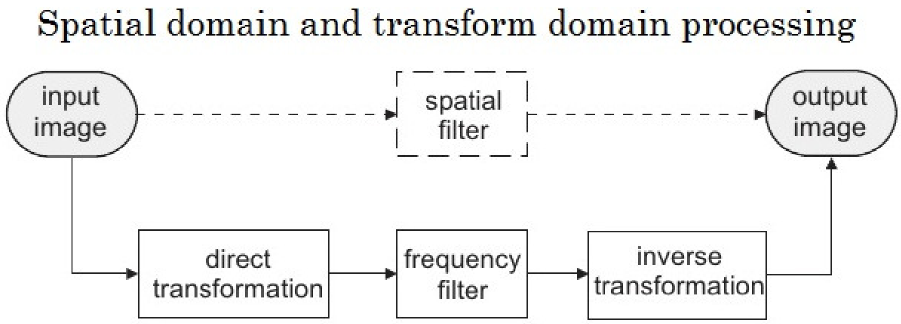


**FIGURE 4:** Spatial and Transform Domain Processing.

## 2.4 Image Fusion Methods

### 2.4.1 Average Pixels

In this method the resultant fused image is obtained by taking the average intensity of corresponding pixels from both the input image.

$$F(i,j) = ( A(i,j) + B(i,j) ) / 2$$

A(i,j), B(i,j) are input images and F(i,j) is fused image.

### 2.4.2 Select Minimum

In this method, the resultant fused image is obtained by selecting the minimum intensity of corresponding pixels from both the input image.

$$F(i,j) = \min ( A(i,j) , B(i,j) )$$

i ranges from 0 to m

j ranges from 0 to n

A(i,j), B(i,j) are input images and F(i,j) is fused image.

### 2.4.3 Select Maximum

In this method, the resultant fused image is obtained by selecting the maximum intensity of corresponding pixels from both the input image.

$$F(i,j) = \max ( A(i,j) , B(i,j) )$$

i ranges from 0 to m

j ranges from 0 to n

A(i,j), B(i,j) are input images and F(i,j) is fused image.

# 3. PROPOSED METHOD

The data structure used to represent image information can be critical to the successful completion of an image processing task. One structure that has attracted considerable attention is the image pyramid. This consists of a set of lowpass or bandpass copies of an image, each representing the pattern information of a different scale.

The image pyramid is a data structure designed to support efficient scaled convolution through reduced image representation. Typically, in an image pyramid every level is a factor of two smaller as its predecessor, and the higher levels will concentrate on the lower spatial frequencies. An image pyramid does contain all the information needed to reconstruct the original image.

### 3.1 System Architecture

The input images are given to a pyramid to be decomposed into a pyramid and then reconstructed through blending. Simultaneously the input images are wavelet transformed and the inverse of wavelet reconstructs the image. Then the pyramid blended image and the wavelet transformed images are fused to produce a credible contrast enhanced image.

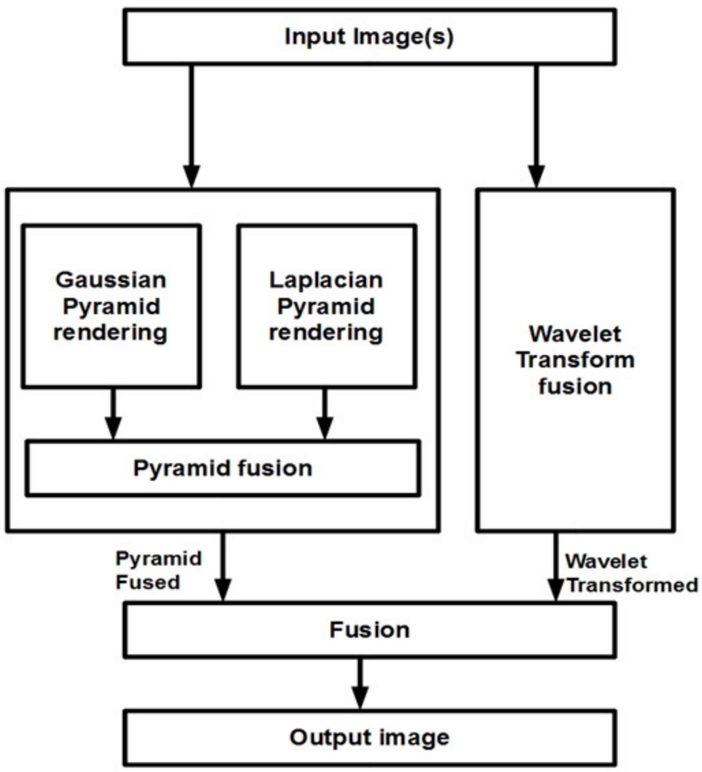


**FIGURE 5:** Proposed System Architecture.

### 3.2 Pyramid Construction

An image pyramid [13] is a hierarchical representation of the image. It is a collection of images at different resolutions. An image pyramid is constructed where all images arise from a single original image - that is successively downsampled until some desired stopping point is reached.

To build the pyramid the image needs to be converted into images of sizes different than its original. For this, there are two possible options:

1. Upsize the image (zoom in)
2. Downsize it (zoom out)

To achieve these, two kinds of image pyramids are used.

1. Gaussian pyramid: Used to downsample images.
2. Laplacian pyramid: Used to reconstruct an upsampled image from an image lower in the pyramid (with less resolution).

### 3.3 Pyramid Levels

The number of levels can be found by taking the log(minimum(height,width))/log(2) and finding its floor value [13].

### 3.4 Gaussian Pyramid

Gaussian Pyramids can be constructed by normalizing the pixels, symmetry of the pixels or through equal contribution of the pixels. They are done previous to pyramid construction. Normalizing method is most efficient as it makes use of the 4-point neighborhood pixels. The 4-point +i weights should be equal to 1. It can be done by multiplying it by Kernel values that sum as 1. The kernel can be constructed as a separable filter. The convolution of the image G by the kernel values G' gives a low-pass filtered resolution of the image. It is decimated to keep 2ˆ(N-1)+1 level.

### 3.5 Laplacian Pyramid

Laplacian Pyramids can be constructed by Li=Gi-Gi' where i represents the level and Gi' is Gi'=(Gi-1)*(Gi+1).

### 3.6 Wavelet Transform

The Fourier transform [14,15] is a useful tool to analyze the frequency components of the signal. However, if taking the Fourier transform over the whole time axis, the instant at which a particular frequency rises cannot be determined. Wavelet transform is the solution to these. Wavelet transforms are based on small wavelets with limited duration. The translated-version wavelets locate where concerned; whereas the scaled-version wavelets allows analyzing the signal in a different scale.

Since image is 2-D signal, 2-D discrete stationary wavelet transforms are used. After one level of decomposition, there will be four frequency bands, namely Low-Low (LL), Low-High (LH), High-Low (HL) and High-High (HH). The next level decomposition is just applied to the LL band of the current decomposition stage, which forms a recursive decomposition procedure. Thus, an N-level decomposition will finally have 3N+1 different frequency bands, which include 3N high frequency bands and just one LL frequency band. The frequency bands in higher decomposition levels will have smaller size.

## 4. RESULTS

**FIGURE 6:** Input image sets - a camera image and a contrast image of the same.

**FIGURE 7:** The wavelet transformed (left) and pyramid fused (right) images.

**FIGURE 8:** Output image from our proposed method.


**FIGURE 9:** Close up of the car. In the original image the registration number is not clear (left) whereas in the fused output (right) it is clearly visible.

| | ENTROPY | CONTRAST |
|---|---|---|
| **ORIGINAL IMAGE** | 7.6019 | 0.5971 |
| **WAVELET** | 7.8273 | 0.9297 |
| **FUSED** | 7.8910 | 1.1529 |

**TABLE 1:** Comparative analysis of the metrics.

Image entropy is used to describe the amount of information of an image. The entropy for the original image is at 7.6019. The entropy gives the value for the information from the image. Whereas the entropy for the wavelet transformed image is 7.8273. The wavelet transformed image has improved the image and has made some information visible. It is very weak on boundaries. That is the edges of the objects in the image are not well detected.

The entropy of the proposed method is 7.8910. The proposed method has a 3.732% difference compared to the input image and a 0.8105% difference compared to the Wavelet Transformation method. So, the information content has definitely improved. This helps in visibility of more details in the image.

Contrast is the difference in color that makes an object distinguishable. Contrast is determined by the difference in the color and brightness of the object and other objects within the same field of view. The contrast of the image is 0.5971 and the contrast is improved by applying Wavelet Transformation to 0.9297. The contrast by the proposed method is 1.1529. The contrast helps in gaining more details and information from the image. The contrast makes the image satisfy the human visual system with easy to analyze details.

Thus looking at the evaluated results it is elucidated that the fused output of a pyramid fused and wavelet transformed image is better than the existing methodologies. The contrast is improved and the entropy is efficaciously increased. The visibility of the fused output can prove effective in crime investigation. Thereby the method of image fusion – image enhancement is found to be literately and logically effective.

The method proposed can be used for image recognition and information interpretation. As from the test image, we can infer that the fused output of the proposed method has not only improved the images visually but also has made the image interpretable compared to the original input image.

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