Image Enhancement by Fusion in Contourlet Transform

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Abstract: Most existing image enhancement algorithms work on a single image. Their performance is limited to the capacity of the sensor by which the image is taken. In some cases they completely fail to provide us the necessary enhancements. This paper proposes a composite image approach for enhancing still images. The approach proposed combines the relevant features of the input images and produce a composite image which is rich in information content for human eye. The input images are first decomposed into multiple resolutions by using the contourlet transform which provides a better representation than the conventional transforms. Transformed coefficients are combined with a predefined fusion rules. The resultant image is found by performing inverse contourlet transformation of the composite image. The results found are encouraging and the algorithm does not introduce any distortion for applications in low light and/or non uniform lighting conditions. The composite image also contains almost all of the salient features of the input images
Keywords : Image Enhancement, Single image, Composite Image, Fusing Images, Contoulet Transform**.**

1. Introduction

Image enhancement is a process of improving the interpretability or perceptibility of information in images for human viewers or to provide better input for other automated image processing techniques. Low visibility in still images is generally presented in as dark shadows, over bright regions and blurred details.

One possible way to solve the above problems is to apply image enhancement original single image. A lot of algorithms [1-4] have been developed in this area and their performance is limited with the performance of the sensors in which the image is taken. Either due to design or observational constraints a single image approach usually fails in providing the necessary enhancements.

The other possible approach is to enhance image features by using the information gathered from multiple images. For example, one can combine image from a night vision camera with an image from a visual camera. In this case, the night vision camera is capable of taking images in low light condition but it cannot capture any color information. On the other hand, the visual camera can take the color information but the image captured will have low contrast and dark shadows. Combining these two images one can successfully capture all the relevant information. This process is called image fusion. Since the fused image generally possesses more scene information than any single input image, image fusion can also be considered as an image enhancement process. The multi sensor image fusion has become less expensive as the price of image sensors has dropped in the last decades.

The combination process can take place at different levels of information representation. A common categorization is to distinguish between pixel and region level [5]. Image combination at pixel level is the integration of low-level information, in most cases physical measurements such as pixel intensity. It generates a composite image in which each pixel is determined from a set of corresponding pixels in the various sources. In this paper a pixel based approach transformed image is used to compared for activity measure.

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The first multiresolution based image fusion approach was proposed by Burt [6]. This implementation used a Laplacian pyramid and a "choose max" selection rule that, at each sample position in the pyramid, the source pyramid coefficient with the maximum value is copied to the composite pyramid. Toet [7-8] proposed using a ratio of low pass pyramid and the same selection rule which is used by Burt above to fuse IR and visible image. Burt and Kolczynski [9] proposed another method which introduces the concept of activity measure and match measure using the wavelet transform. Several other methods exist in the literature [10-16] focused on fusing dual (or composite images) with various multi resolution transformation techniques.

This propose a contourlet transform based multresolution approach to combine (or fused) the two source images for vision clarity. The rest of the paper is divided as follows, in section two(2) the contourlet transform is discussed briefly but in detail. Section three(3) details out the composite images approach proposed in the paper for image enhancement. Section four(4) provides the comparison results and discussion part and finally section five(5) concludes the paper.

2. Introduction to Contourlet Transform

For image enhancement, one needs to improve the visual quality of an image with minimal image distiortion. Wavelet bases present some limitations, because they are not well adapted to the detection of highly anisotropic elements such as alignments in an image. Recently Do and Vetterli [12] proposed an efficient directional multi resolution image representation called the contourlet transform. Contourlet transform has better performance in representing the image salient features such as edges, lines, curves and contours than wavelet transform because of its anisotropy and directionality. It is therefore well-suited for multi- scale edge based color image enhancement.

The contourlet transform consists of two steps which is the sub band decomposition and the directional transform. A Laplacian pyramid is first used to capture point discontinuities, then followed by directional filter banks to link point discontinuity into lineal structure. The over all result is an image expansion using basic elements like contour segments, thus the term contourlet transform being coined. Figure 1 shows a flow diagram of the contourlet transform.

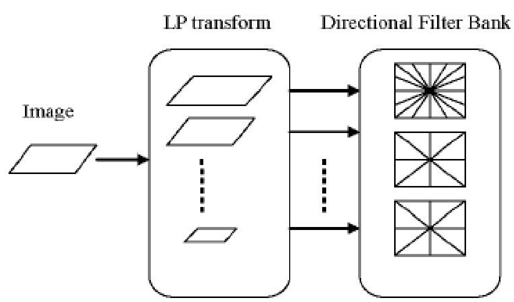


Figure 1. Contourlet transform framework.

3. Image Enhancement using composite images

Today, most composite image approaches employ pixel fusion methods. The advantage of pixel fusion is that the images used contain the original information. Furthermore, the algorithms are rather easy to implement and time efficient. As the present author observed before in one of the findings [13], an important pre-processing step in pixel based fusion methods is image registration, which ensures that the data at each source is referring to the same physical structures. In the remainder part of the paper, it will be assumed that all source images have been registered.

Figure 4 shows a detailed block diagram of the proposed scheme in flow layout. The framework contains eight modules and the description of each of the building blocks is given below in each process block.

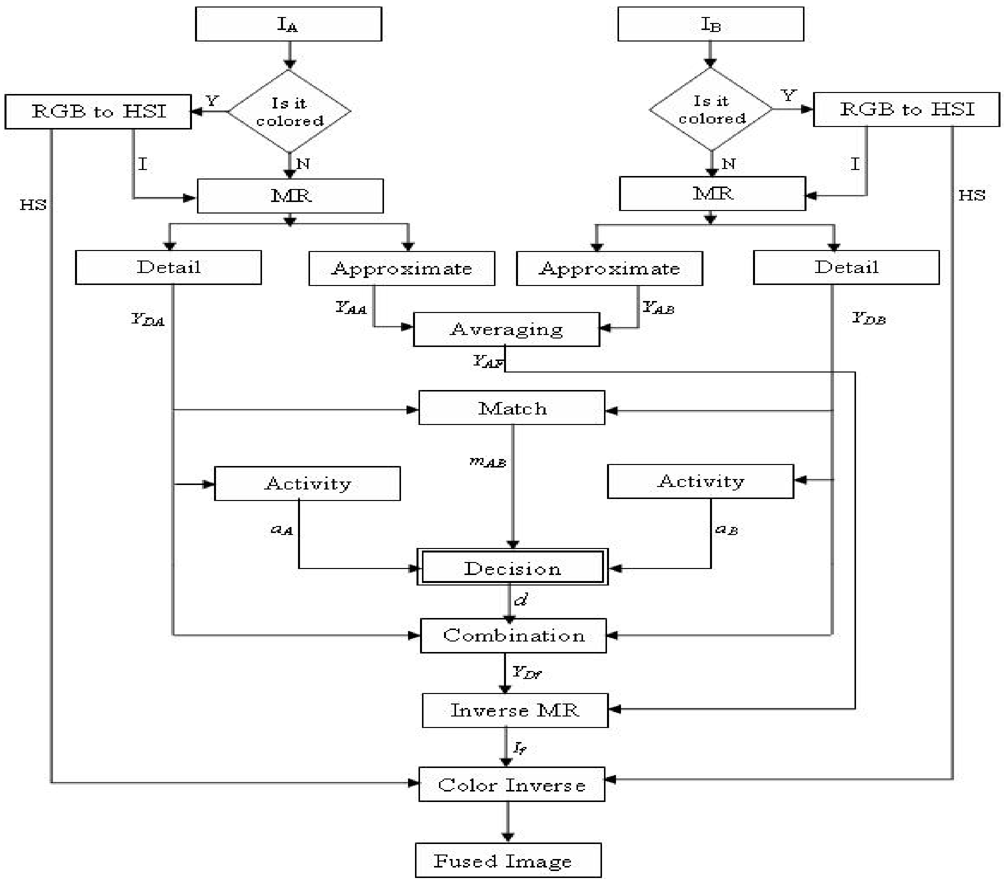


Figure 4. General Composite image enhancement Frame work

A. MR Analysis:

This block computes an MR (or multi-resolution) decomposition using the contourlet transforms from the input sources. The contourlet transform generates approximate and detail coefficients. Since both (approximate and detail) of their different physical meanings, thus they are treated by the combination algorithm in a different manner. The term approximate and detail coefficient will be explained in the later stage.

The activity measures of the source images (Figure. 5(a)) can be visualized as a gray scale image where higher gray values pixel indicates a higher saliency of that pixel. The man in Figure. 5(b) shows a higher gray level thus its saliency is very high.

(a)

(b)

(c)

Figure 5. Visualization of the Activity measures (a) Source Image (b) Visual Image (c) night vision image

F. Match measure:

It is used to quantify the degree of similarity between the sources. Precisely $m_{AB}^{k}(x,y)$ reflects the resemblance between Y_{DA} and Y_{DB}. The match measure tells where the sources are different and to what extent they differ. We can use this information to appropriately combine them. In our algorithm it is defined as a normalized correlation average over neighborhood of the samples as shown in equation (3). Where W^k being window of size either 1*x*1 3*x*3 or 5*x*5 centred at the origin.

$$m_{AB}^{K}(x,y)=\frac{2\sum_{\Delta n\in W^{k}} Y_{A}^{K}\left(x+\Delta n, y+\Delta n\right) Y_{B}^{k}(x+\Delta n, y+\Delta n)}{a_{A}^{k}(x,y)+a_{B}^{K}(x,y)} \tag{3}$$

no colour information. The composite image is precise and contains almost all relevant information for clear visual perception.


(a) (b)

(c)

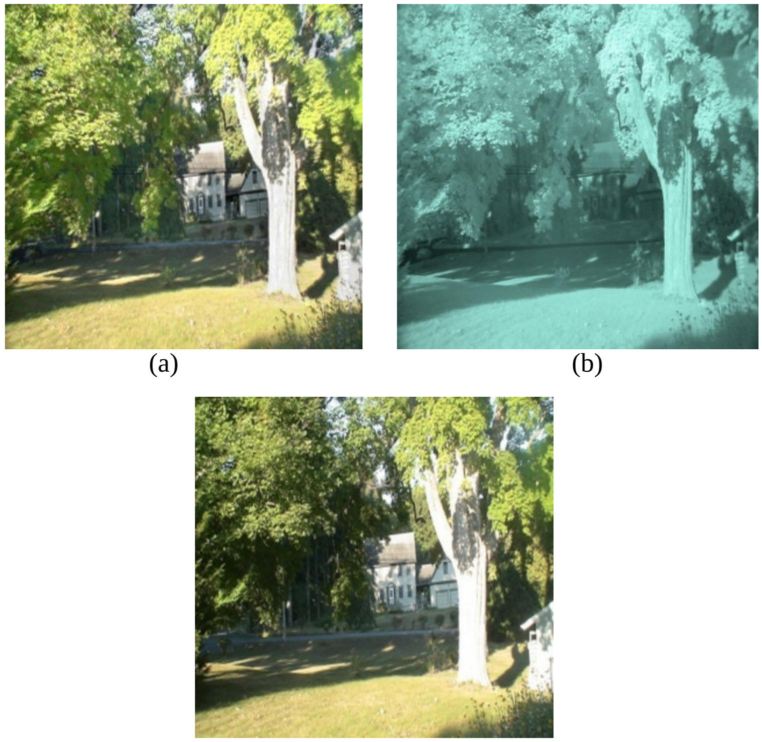
Figure 6. Case Study I, a) visual image b) night vision image c) composite image

C. Case Study III

The sample result on Figure 7 shows a house and trees. It is used by permission from [14]. In the visual image of Figure 7(a) the color is clear and the image is so natural. The infrared image of Figure 7(b) shows the same image but the normal color information is lost but this image shows the details of the house and the electric cable in front of the house which is not visible in the visual image. The composite image in Figure 7c shows more complete information with no color degradation.

D. Case Study IV

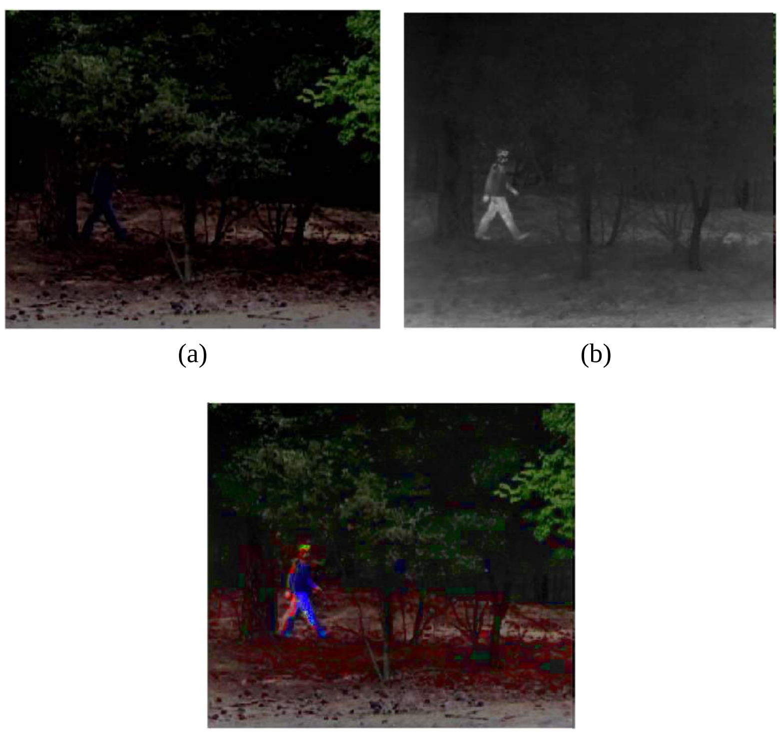
This approach can also be used in security surveillance applications in Figure 8. This image is taken in a typical area surveillance scenario for monitoring an outdoor scene in a bad visibility condition. It is used by permission from [8]. A man is walking through the scene behind the bushes. He is barely visible in the visual image of Figure 8a while the night vision camera in Figure 8b captures him clearly but not the details of the vegetation. Thus appropriately combining these two images will generate a complete composite image as shown in Figure 8c.



(a) (b)

(c)

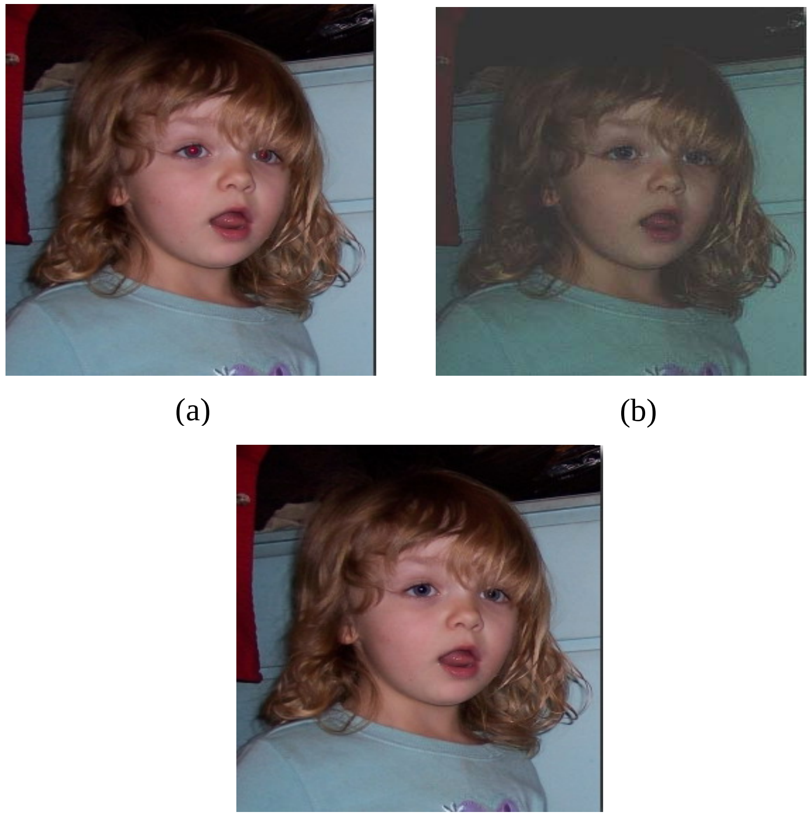
Figure 7. Case Study III, a) visual image b) Infrared image c) composite image



(a) (b)

(c)

Figure 8. Case Study IV, a) visual image b) night vision image c) composite image



(a) (b)

(c)

Figure 8. Red eye removal

(a) Image taken when the flash is on (b) image taken when the flash is off (c) fused image

5. Conclusion

In many applications human perception of the fused images is of a fundamental importance and as a result the enhancement results are mostly evaluated by subjective criteria.
The experimental results show that the fusion algorithm gives encouraging results for both multi modal and multi focal images. Since the image salient features such as edges lines and contours are well represented using the contourlet transform, the fusion process did not introduce any distortion to the original image.

Directional information introduced by the contourlet transform yields the best description of the all the salient information in the both test images. Thus the composite image is more complete and looks natural and the noise level is minimal. Utilization of the composite image is expected to increase the performance of the subsequent processing tasks. By integrating information, this approach can reduce dimensionality. This results in a more efficient storage and faster interpretation of the output. Using redundant information, the composite image increases the accuracy as well as reliability, and using complementary information, the process also improves interpretation capabilities with respect to subsequent tasks. This leads to more accurate data, increased utility and robust performance.

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