

Multi Exposure Image Fusion based on PCA

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ABSTRACT

We face a lot of challenges in image exposure (light/unit area), while an image is captured using a digital camera. To solve this problem, multiple exposure images are combined by different fusion techniques to generate HDR(High dynamic range) image. In order to fuse these images to form a desired HDR image, different techniques are adopted. In this paper a new method is developed using statistical values and component analysis. The algorithm is tested for different images, for comparison of existing methods-evaluation metrics like SSIM, MSE and PSNR are used.

Keywords: Colour space, Principal component analysis, SSIM, MSE, PSNR.

I. INTRODUCTION

Exposure (light/unit area) problem occurs due to the low dynamic range of digital cameras. The problem of under exposure or over exposure can be solved by conversion techniques and fusion methods. The range of a modern digital camera image sensor is around 2^8 - 2^{14} , and its logarithm with base 2 is measured in *stops*. A conventional DSLR camera can correctly capture scenes with 8 – 12 stops dynamic range, while professional movie cameras, such as the Red Epic, can capture scenes with 14 stops. The human visual system responds correctly to all the scenes of the natural world, where the dynamic range exceeds 24 stops. Consequently, in high dynamic range scenes, a picture capture by an imaging camera will often results into several areas being under or over exposure, i.e. blacker or whiter colours than in real image.

The solution to this problem is to use *multi-bracketing photography*. This is to say, the scene is captured using the same imaging sensor taking multiple pictures at different exposures. In this manner, the single area will be captured with three different exposure setups. Commonly called as over exposure (whiter colour), correct exposure and under exposure (blacker colour) [1]. There has been a lot of research in the field of multi exposure image fusion, which would solve problems to an extent, however lot of steps exists in this area as digital media and entertainment industry completely depends on digital cameras.

II. THE PROPOSED MULTI EXPOSURE IMAGE FUSION SYSTEM

The proposed system is described by Flow chart. The next step is going to discuss in blocks.

A. Image Alignment- Colour Space

In our work, we used the common three exposure images setup (under-exposed, correct-exposed and over-exposed), however, the system can work with an arbitrary number of inputs. The first step was to check whether the three input images are in same dimension and also same format. To address this problem, we used the image alignment method.

The next step was to separate the luminance and chrominance components from the three RGB colour channels. To achieve this, we converted the input RGB images to the YCbCr (Colour Space) system [4], which offers this type of colour separation. RGB has the standard computer visual system, whereas YCbCr has the standard human visual system. The inspiration comes from the human visual system. As it is also noted in the JPEG compression scheme, humans tend to pay greater attention to detail that exist in the luminance/brightness channel and are less attentive to errors in the colour channels. The conversion process of RGB to YCbCr4:2:2 is not possible directly, it will convert in four steps process internally as RGB to YCbCr4:4:4, YCbCr4:4:4 to YCbCr4:2:2, YCbCr4:2:2 to YCbCr4:4:4, YCbCr4:4:4 to RGB, in that the Y represents the luminance component of an image and also the Cb and Cr represents chrominance components of an image.

$$\left. \begin{aligned}
 Y &= 16 + \frac{65.738R}{256} + \frac{129.057G}{256} + \frac{25.064B}{256} \\
 Cb &= 128 - \frac{37.945R}{256} - \frac{74.494G}{256} + \frac{112.439B}{256} \\
 Cr &= 128 + \frac{112.439R}{256} - \frac{94.154G}{256} - \frac{18.285B}{256}
 \end{aligned} \right\} \text{----- (1)}$$

From the colour space of input RGB image, the combination of luminance and chrominance channel of YCbCr images is possible for getting Second image.

B. Image Fusion - Synthesis

Image fusion is the process of collecting important information from two or more images and produce fewer or single image. That single image is more informative than the input images and also it consists of all necessary things that presents in the input images. The fused image should have more information; it is very useful for human visual system and machine perception. The Principal component analysis [5] is a vector space transform, often used to reduce multidimensional data sets to lower dimension for analysis, in other words PCA transform the number of correlated variables into uncorrelated variables called principal components. Where the use of PCA data size is compressed as well as dimensions are altered then there is no much loss of information at the input image.

Due to insertion of analogues and interrelating information, the lighting and overall information is increased. In Mertens et al proposed a multi exposure fusion [1] on HDR images. A multi exposure means it is the superimposition of two or more exposure images to create a single image with having high dynamic range [2]. The high dynamic range is a high dynamic image (HDR), that technique is used in imaging for getting better dynamic range of luminosity than is possible with maintain standard photographic technique. The main aim is to produce clear luminance of the standards of human visual system. Why because the human brain will always interrupts that information, so that the human can see only wide range of light conditions, i.e. HDR(7680x6870 pixels) image produce better range of luminance levels that can be getting from using more traditional methods like as real-world scenes and sun light. There are two types of HDR images are available those are compute renderings and images resulting from merging multiple Low Dynamic range photographs. The HDR images can capture by using Modern CMOS sensors and oversamples binary image sensor.

In the process of colour spaces the noise is occurred, i.e. Gaussian noise [6] (electrical noise) so, that to reduce these noise by using the spatial filter. However, it must be kept in mind that when smoothing an image, we reduce not only the noise, but also the fine scaled image details because they also correspond to blocked high frequencies.

C. Evaluation Quality Measures

- i. SSIM: - The structural similarity index is a method for predicting the perceived quality of digital television and cinematic picture, as well as other kinds of digital images and videos. SSIM is used for measuring similarity between two images. The SSIM is a measurement or prediction of image quality is based on an initial uncompressed or distortion- free image as reference.

$$SSIM(x, y) = \frac{(2\mu_x\mu_y+c_1)(2\sigma_{xy}+c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)} \quad \text{----- (2)}$$

Where as

$$\mu_x = \frac{1}{T} \sum_{i=0}^T X_i, \mu_y = \frac{1}{T} \sum_{i=0}^T Y_i$$

$$\sigma_x^2 = \frac{1}{T-1} \sum_{i=1}^T (x_i - \bar{x})^2, \sigma_y^2 = \frac{1}{T-1} \sum_{i=1}^T (y_i - \bar{y})^2$$

$$\sigma_{xy}^2 = \frac{1}{T-1} \sum_{i=1}^T (x_i - \bar{x})(y_i - \bar{y})$$

Where μ is the average of the image and Σ is the variance of the image.

- ii. MSE: - The Mean Square Error, MSE of an estimator measure the average of the squares of errors that is, the MSE is computed by averaging the squared intensity of the original image and the resultant image pixels.

$$MSE = \frac{1}{NM} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} e(m, n)^2 \quad \text{----- (3)}$$

Where m is the input image and n is the reference image.

- iii. PSNR: - Peak - signal to Noise ratio, SNR is a mathematical measure of image quality based on the Pixel difference between two images. The SNR measure is an estimate of quality of reconstructed image compared with original image, PSNR is defined is

$$PSNR = 10 \log S^2/MSE \quad \text{----- (4)}$$

Where $S = 255$ for an 8-bit image. The SNR is basically the SNR when all pixel values are equal to the maximum possible value.

III. ALGORITHM

- Step1:** Multi exposure images are acquired (read) from a digital camera.
- Step2:** Under exposure (UE), correct exposure (CE) and Over exposure (OE) images are identified and resize to 256X256 pixels.
- Step3:** The captured images are in RGB format will be converted to YCbCr format.
- Step4:** Individual luminance and chrominance parameters of UE, CE, and OE are added to generate a hybrid image.
- Step5:** Different combinations of fusions are applied to generate multiple fused images like UE(Y) + CE (CbCr), UE(Y) + OE (CbCr), CE(Y) + UE (CbCr), CE(Y) + OE (CbCr), OE(Y) + UE (CbCr), OE(Y) + CE (CbCr).
- Step6:** To remove Gaussian noise from the poor lighting images spatial filtering is done.
- Step7:** A Hybrid image with HDR quality is obtained.

Step8: To test the performance of the algorithm, SSIM, PSNR and MSE are calculated.

IV. FLOW CHART

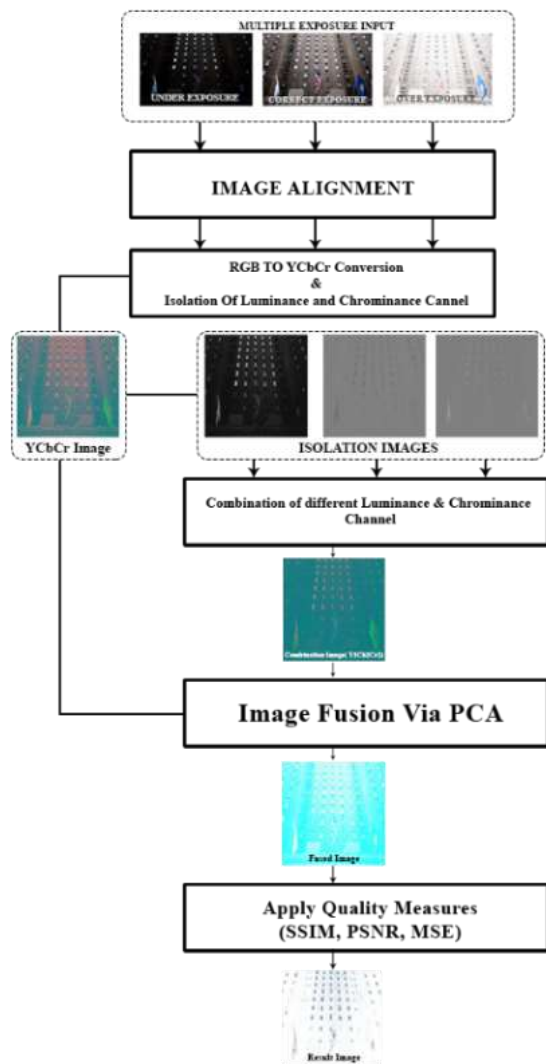


Figure 1. Proposed method flowchart

V. TABULAR COLUMN

In the below table we can see the results of the YCbCr format images of the captured input images with the quality measures of Structural Similarity Index (SSIM), peak Signal-to-Noise ratio (PSNR) and Mean Square Error(MSE).

Table 1: Results of YCbCr images of Input Images

Image Type	SSIM	PSNR	MSE
YCbCr of Under exposure(I4)	0.9858	32.8256	33.9250
YCbCr of Correct exposure(I5)	0.5020	27.8610	106.4105
YCbCr of Over exposure(I6)	0.9638	29.9212	66.2163

In the below table we can see the results of the combination of luminance component and the chrominance components of the two different exposure images like as Y (under exposure) CbCr (correct exposure) with the quality measures of Structural Similarity Index (SSIM), peak Signal-to-Noise ratio (PSNR) and Mean Square Error(MSE).

Table 2: Results of Combination of Luminance and Chrominance Images

Image Type	SSIM	PSNR	MSE
I7	0.9852	32.5394	36.2360
I8	0.9854	32.6752	35.1205
I9	0.8736	27.9563	104.0995
I10	0.8733	27.9067	105.2950
I11	0.9643	30.0003	65.0209
I12	0.9632	29.8486	67.3318

In the below table we can see the results of the fusion of the two different images like YCbCr of the Under exposure with the luminance of correct exposure and chrominance of under exposure image with the quality measures of Structural Similarity Index (SSIM), peak Signal-to-Noise ratio (PSNR) and Mean Square Error(MSE).

Table 3: Results of Fused Images

Image Type	SSIM	PSNR	MSE
I13	0.9656	26.3824	149.5691
I14	0.9646	26.3599	150.3455
I15	0.9858	29.3303	75.8660
I16	0.8676	29.3243	75.9717
I17	0.9638	26.3009	152.4032
I18	0.9646	26.3384	151.0933
I19	0.8466	29.1658	78.7959
I20	0.8460	29.0874	80.2306
I21	0.8683	29.3172	76.0966
I22	0.9858	29.3094	76.2331
I23	0.9858	29.2081	78.0313
I24	0.8493	29.1514	79.0572

Where I7(Y1Cb2Cr2), I8(Y1Cb3Cr3), I9(Y2Cb1Cr1), I10(Y2Cb3Cr3), I11(Y3Cb1Cr1), I12(Y3Cb2Cr2) and I13(I4 + I9), I14(I4 + I10), I15(I4 + I11), I16(I4 + I12), I17(I5 + I7), I18(I5 + I11), I19(I5 + I11), I20(I5 + I12), I21(I6 + I7), I22(I6 + I8), I23(I6 + I9), I24(I6 + I10).

Y1: Luminance of under exposure image

Cb1Cr1: Chrominance of under exposure image

Y2: Luminance of correct exposure image

Cb2Cr2: Chrominance of correct exposure image

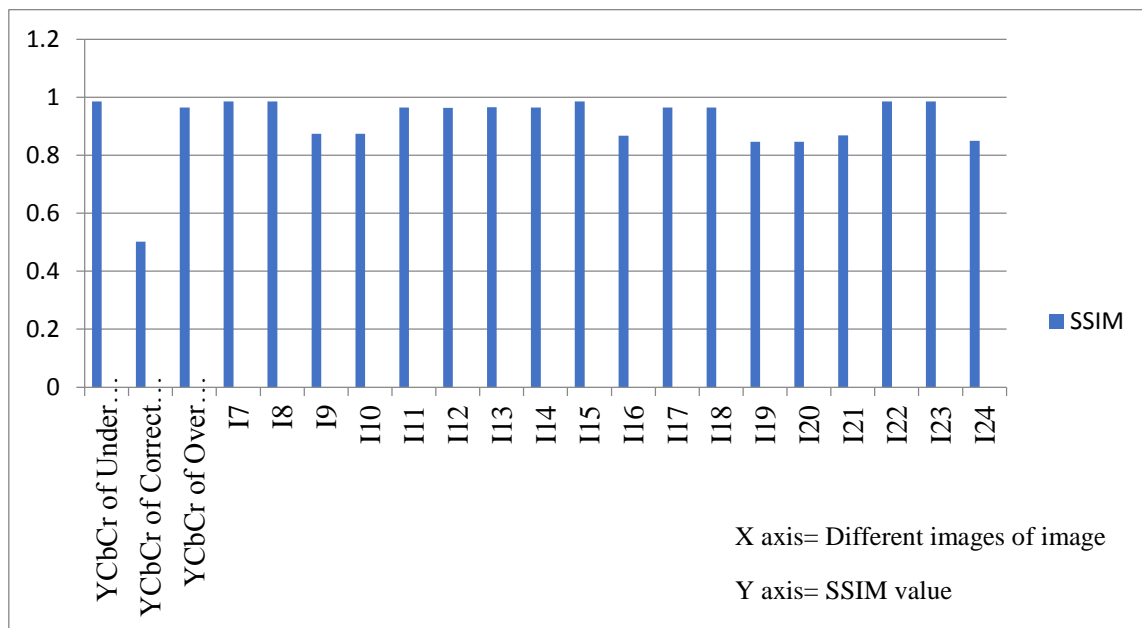
Y3: Luminance of over exposure image

Cb3Cr3: Chrominance of over exposure image

The images I7 to I12 represents the combination of the luminance and chrominance components of the two different exposure images and also the images I13 to I24 represents the Fusion of the YCbCr image with the combination image.

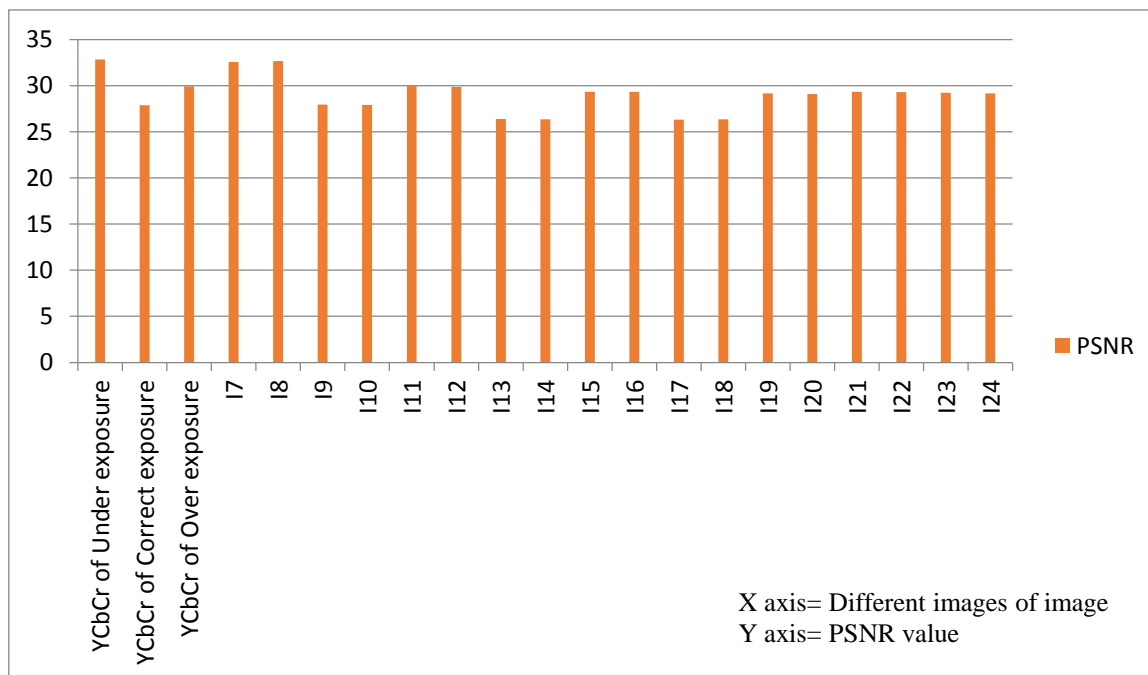
VI. GRAPH

In the below graph we see the results comparison with the Structural Similarity Index (SSIM) of the YCbCr images, Combination images and Fused images.



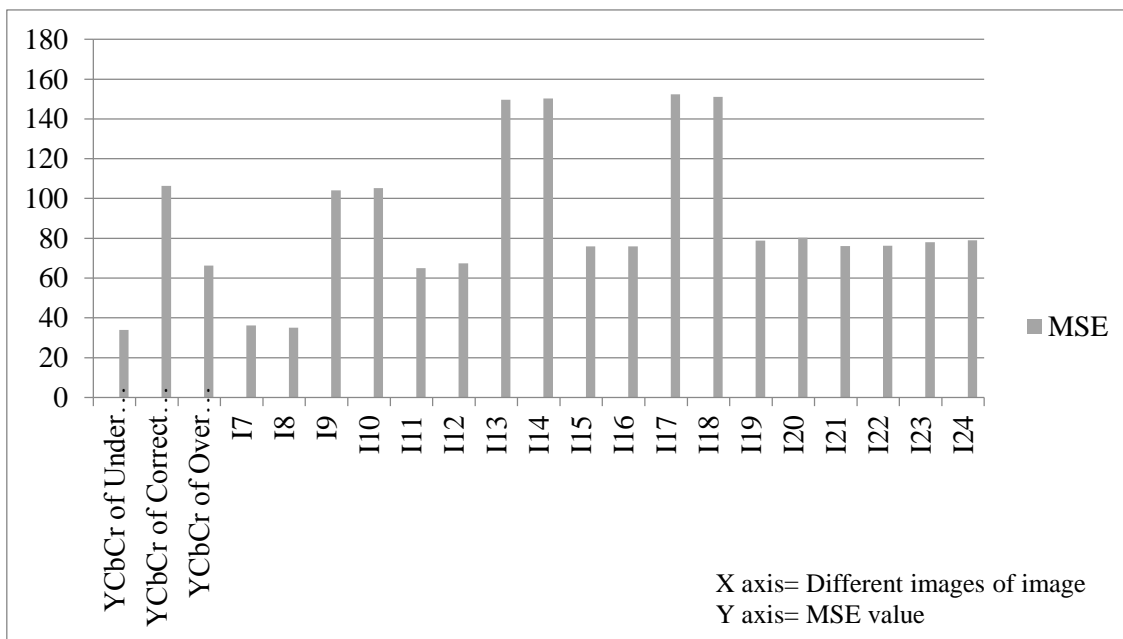
Graph 1: SSIM for YCbCr, Combination and Fused Images

In the below graph we see the results comparison with the Peak Signal –to-Noise ratio (PSNR) of the YCbCr images, Combination images and Fused images.



Graph 2: PSNR for YCbCr, Combination and Fused Images

In the below graph we see the results comparison with the Mean Square Error (MSE) of the YCbCr images, Combination images and Fused images.



Graph 3: MSE for YCbCr, Combination and Fused Image

VII. EXPERIMENT IMAGES

The below figure (1) shows the input images those are under exposure, correct exposure and over exposure images.



Fig 1: Input Images

The below figure (2) show the Conversion of the RGB format to YCbCr format images of the given input under exposure, correct exposure and over exposure images.

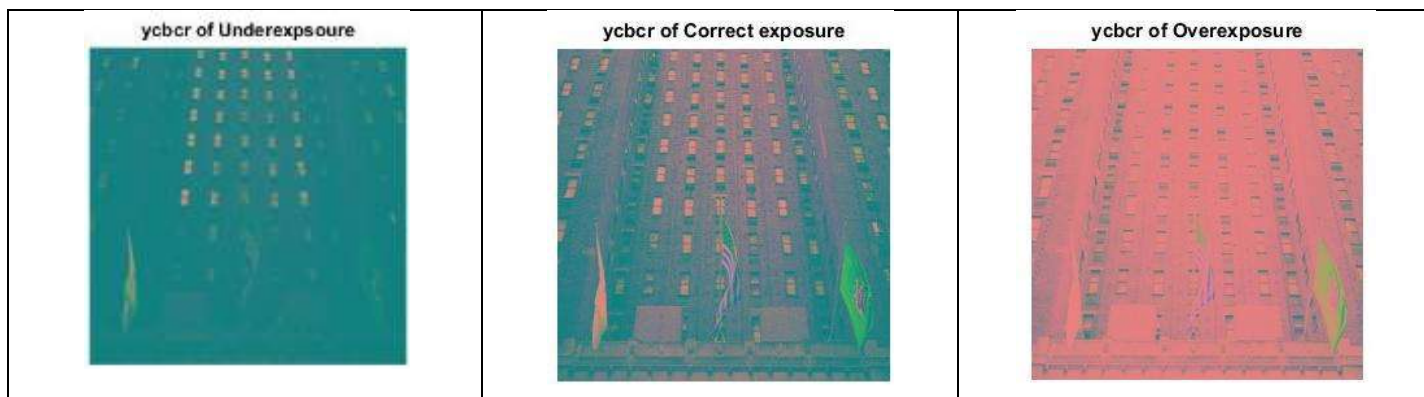


Fig 2: RGB to YCbCr Converted Images

The below figure (3) show the Structural Similarity Index (SSIM) image of the YCbCr format images.



Fig 3: Results Compared with Converted Images

The below figure (4) show the Structural Similarity Index (SSIM) image of the combination of the luminance and chrominance components of the two different exposure images.

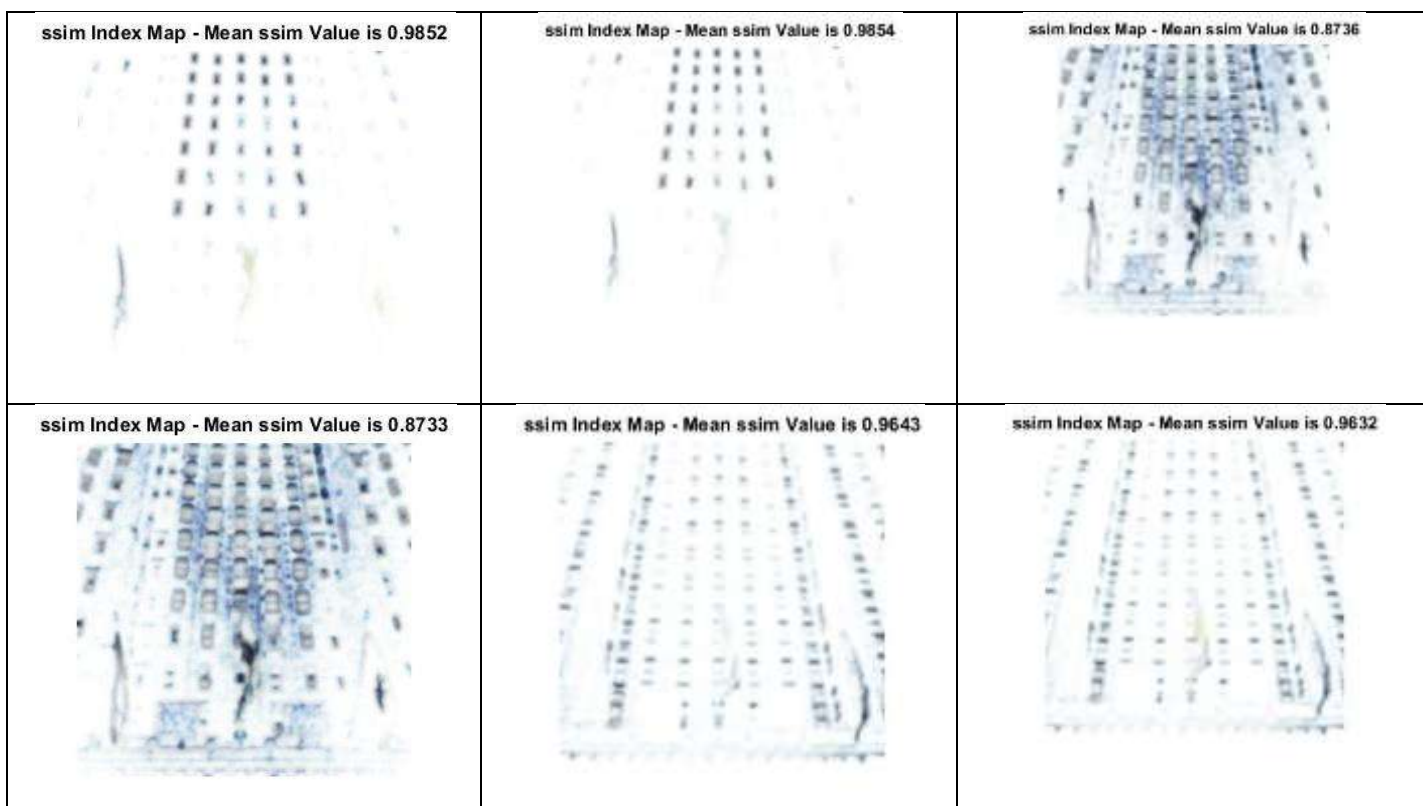


Fig 4: Results Compared with Combination Images

The below figure (5) show the Structural Similarity Index (SSIM) image of the Fused images.

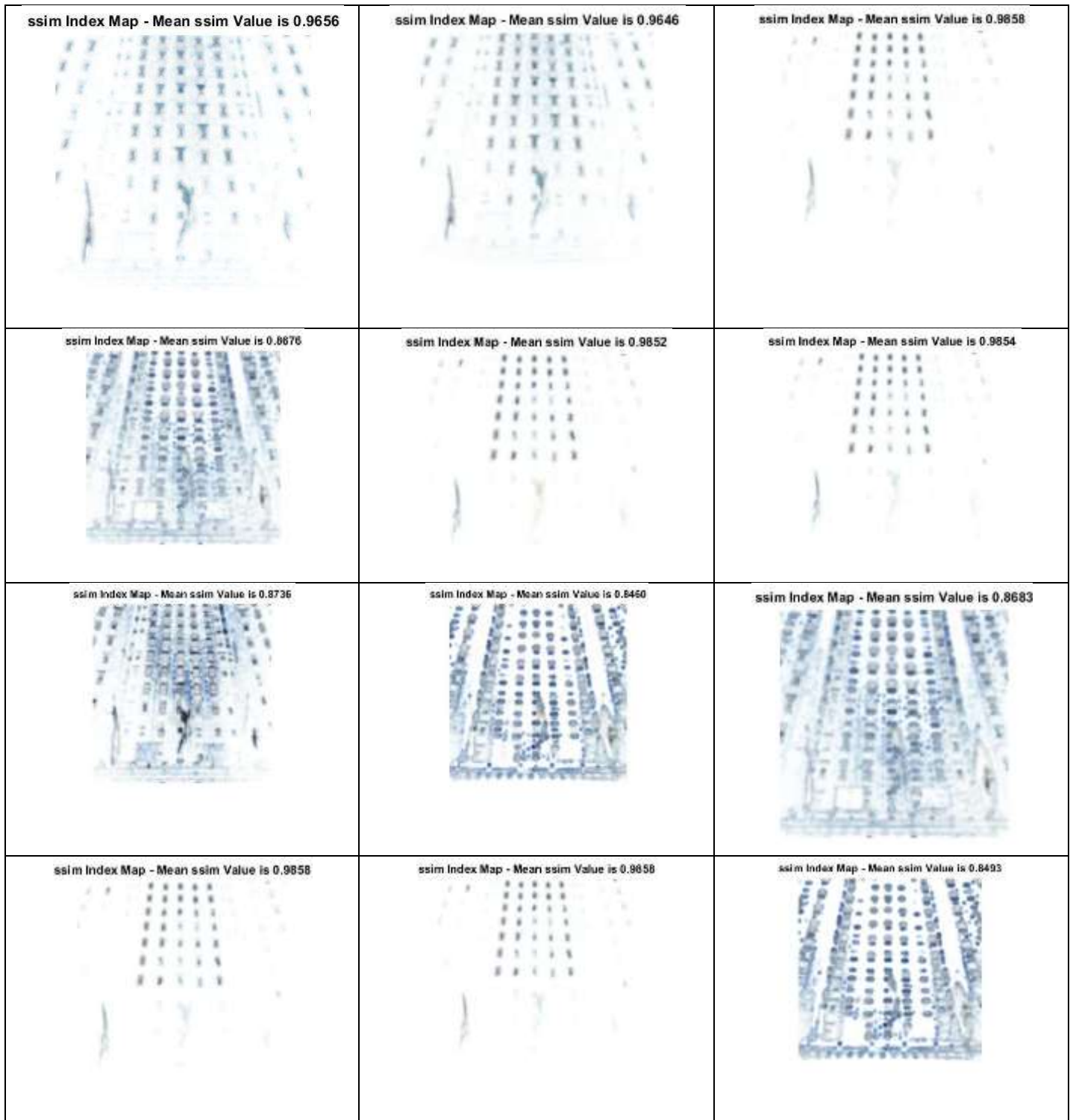


Fig 5: Results Compared with Fusion Images

VIII. CONCLUSION

A new way of fusion algorithm is proposed by combining and fusing luminance and chrominance channels of multi exposure images. Based on the evaluation quality measures like SSIM, MSE and PSNR, A high quality image is obtained with more desired information. The complexity of the algorithm can be reduced by developing a statistical database or neural networks in future.

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