A STUDY ON EIGEN FACES FOR REMOVING IMAGE BLURREDNESS THROUGH IMAGE FUSION

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ABSTRACT

Advances in technology have brought about extensive research in the field of image fusion. Image fusion is one of the most researched challenges of Face Recognition. Face Recognition (FR) is the process by which the brain and mind understand, interpret and identify or verify human faces Face recognition is nothing but a biometric application by which we can automatically identify and recognize a person from the visual image of that person stored in the database. Image fusion is the perfect combination of relevant information from two or more images into a single fused image. As a result the final output image will carry more information as compare to the input images. Thus the main aim of an image fusion algorithm is to take redundant and complementary information from the source images and to generate an output image with better visual quality. In this paper we have proposed a novel approach of pixel level image fusion using PCA that will remove the image blurredness in two images and reconstruct a new de-blurred fused image. The proposed approach is based on the calculation of Eigen faces with Principal Component Analysis (PCA). Principal Component Analysis (PCA) has been most widely used method for dimensionality reduction and feature extraction.

KEYWORDS

De-blurred fused image, Principal Component Analysis, Eigen faces ,empirical mean, peak signal to noise ratio (PSNR)

1. INTRODUCTION

Image fusion produces a single image by combining information from a set of source images together, using data/ pixel, feature or decision level techniques. The main aim of an image fusion algorithm is to take redundant and complementary information from the source images and to generate an output image with better visual quality. In the field of computer vision and robotics systems image fusion results contribute greatly to aid further processing steps for a given task. In practical application scenario image fusion is widely used in the field of medical imaging, security, military, remote sensing, digital camera and consumer use. The proposed approach is based on the calculation of Eigen faces with Principal Component Analysis (PCA). Principal Component Analysis (PCA) has been most widely used method for dimensionality reduction and feature extraction. For simulation and evaluation of the algorithm we have used our own database which contains a total number of 336 images. All the images in the database are able to handle the complicacies of the algorithm. This algorithm can operate on blurredness present in any portion of the two input images.

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2. STUDY ON IMAGE FUSION

Generally a fused image contains greater information as compared to the individual image sources alone. The quality of the fused image is greatly enhanced due to the addition of analogous and complementary information. Firstly, the image should be registered prior to be fused. Data fusion technique is a technique that combines data from different sources together. The main aim of applying fusion is to produce a fused result that interns provide the most detailed and reliable information possible. Fusion of different information sources together also produces a more efficient representation of the data. Resolution can be enhanced to 2 to 5 times using fusion algorithms depending on the number of input images.The fused image can have complementary spatial and spectral resolution characteristics. But, the standard image fusion techniques can distort the spectral information of the multispectral data, while merging. [3]

2.1 WHY IMAGE FUSION IS REQUIRED?

Multisensor data fusion has become a discipline to which more and more general formal solutions to a number of application cases are demanded. Several situations in image processing simultaneously require high spatial and high spectral information in a single image. This is important in remote sensing. However, the instruments are not capable of providing such information either by design or because of observational constraints. The possible solution in this case can be data fusion. [5]

2.2 TYPES OF IMAGE FUSION

There are three main categories of fusion:

a. Pixel / Data level fusion   b. Feature level fusion   c. Decision level fusion

2.2.1 PIXEL LEVEL IMAGE FUSION

Pixel level fusion is the combination of the raw data from multiple source images into a single image. In case of pixel level fusion the fused pixel is taken from a set of pixels from various inputs. The advantage that we get from pixel level fusion is that the original measured quantities are directly taken into consideration in the fusion process [7]. Furthermore, algorithms are computationally efficient and easy to implement. A traditional approach for pixel level fusion is to average the input images. If we average the input images it will reduce the sensor noise but it will also reduce the contrast of the complementary features.

2.2.2 FEATURE LEVEL IMAGE FUSION

In case of feature level fusion, fusion is taken out of the features such as edges or texture. While in case of decision level fusion, fusion is done by combining decision from several experts. In one word we can say that feature level fusion requires the extraction of different features from the source data before the features are actually merged together.

2.2.3 DECISION LEVEL IMAGE FUSION

In case of decision level fusion, fusion is done with the sensor information that is preliminary determined by the sensors. For example we can say, decision level fusion methods include weighted decision methods, classical inference, Bayesian inference and Dempster-Shafer method. In decision level fusion the results from multiple algorithms are combined together to yield a final fused decision.

2.3 ADVANTAGES OF IMAGE FUSION

We can improve the reliability of the image that is fused. (by redundant information) [7].

We can also improve the capability of the fused image (by complementary information) [7].

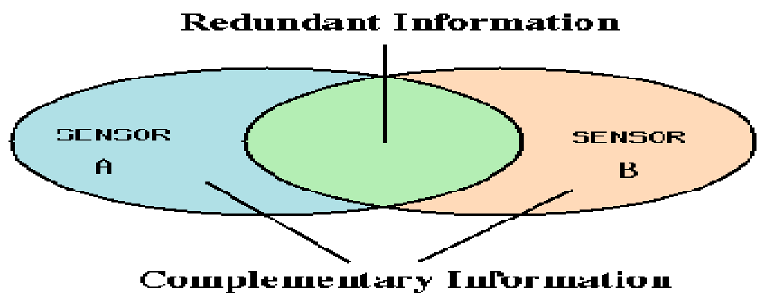


Figure2.3: Diagram showing relation between images from two sensors.

3. REVIEW ON SOME IMPORTANT TERMS AND CONCEPTS

3.1 EIGEN FACES

Eigen faces are a set of eigenvectors used in the computer vision problem of human face recognition. The traditional approach of using eigenfaces for recognition was being developed by Sirovich and Kirby(1987) and was being used by Matthew Turk and Alex pentland in face classification, which is regarded as the first successful example of facial recognition technology. [15]

3.2 EIGEN VECTORS AND EIGEN VALUES

An eigenvector of a matrix is a vector, which when multiplied with the matrix, the corresponding result will always be an integer multiple of that vector. This integer value is nothing but the corresponding eigenvalue of the eigenvector. This relationship can be described by the equation $M \times u = \lambda \times u$, where u is an eigenvector of the matrix M and λ is the corresponding eigenvalue. [15]

3.3 VARIANCE

Variance is the measure of the variability or spread of data in a data set. Variance is considered very much identical to the standard deviation. Variance is simply the standard deviation squared. The formula is denoted as: [6]

$$var(X) = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(X_i - \bar{X})}{(n-1)}$$

3.4 COVARIANCE

Measuring the extent by which the corresponding elements from two sets of ordered data move in the same direction. The formula for covariance is very much identical to the formula for variance. We use the following formula to compute covariance: [6]

$$cov(X,Y) = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{(n-1)}$$

3.5 EMPIRICAL MEAN

The mean subtracted is the average across each dimension. As a result, all the x values have x' (the mean of the x values of all the data points) subtracted, and all the y values have y' subtracted from them. For example, if we have a matrix of 3x2, then the empirical mean will be of dimension 1x2. [6]

3.6 PRINCIPAL COMPONENT ANALYSIS (PCA)

The PCA involves a mathematical procedure that transforms a number of correlated variables into a number of uncorrelated variables called principal components. PCA computes a compact and optimal description of the data set. The first principal component accounts for as much of the variance in the data as possible and each succeeding component accounts for as much of the remaining variance as possible. In the first case principal component is taken to be along the direction with the maximum variance. In the second case principal component is constrained to lie in the subspace perpendicular of the first. Inside this subspace, this component points the direction of maximum variance. In the third case the principal component is taken in the maximum variance direction in the subspace perpendicular to the first two and so on. Principal component analysis is also known as Karhunen-Loève transform or the Hotelling transform. The PCA does not have a fixed set of basis vectors like FFT, DCT and wavelet etc. and its basis vectors depend on the data set. [14]

Let X be a d-dimensional random vector and assume it to have zero empirical mean. Orthonormal projection matrix V would be such that $Y = V^T X$ with the following constraints. The covariance of Y, i.e., cov(Y) is a diagonal and inverse of V is equivalent to its transpose ($V^{-1}=V^T$).

Using matrix algebra:

$$\begin{aligned} \text{cov}(Y) &= E\{YY^T\} \\ &= E\{(V^TX)(V^TX)^T\} \\ &= E\{(V^TX)(X^TV)\} \\ &= V^T E\{XX^T\} V \\ &= V^T \, COV(X)\, V \quad .....(1) \end{aligned}$$

Multiplying both sides of Equation (1) by V, we get

$$V\,\text{cov}(Y) - VV^T \text{cov}(X)\, V - \text{cov}(X)\, V \quad .....(2)$$

Substituting Equation (1) into the Equation (2) gives

$$[\lambda_1 V_1, \lambda_2 V_2, \ldots\ldots, \lambda_d V_d] = [\text{cov}(X)V_1, \text{cov}(X)V_2, \ldots.., \text{cov}(X)V_d] \quad .....(3)$$

This could be rewritten as

$$\lambda_i V_i = \text{cov}(X) V_i \quad .....(4)$$

3.6.1 ALGORITHM FOR COMPUTING PCA

Let the source images (images to be fused) be arranged in two-column vectors. The steps which is considered to map this data into 2-D subspaces are: [14]

i. Organize the data into column vectors.

ii. Compute the empirical mean along each column.

iii. The empirical mean vector M_e has a dimension of 1 x 2.

iv. We have to subtract the empirical mean vector M_e from each column of the data matrix Z. Thus, the resulting matrix X is of dimension n x 2.

v. Find the covariance matrix C of X i.e. $C=XX^T$ mean of expectation = cov(X)

vi. Then we have to compute the eigenvectors V and eigenvalue D of C and sort them by decreasing eigen value. Both V and D are of dimension 2 x 2.

vii. Consider the first column of V which corresponds to larger eigenvalue to compute P_1 and P_2 as:

$$P_1 = V(1)/\Sigma V \text{ and } P_2=V(2)/\Sigma V$$

3.7 PEAK SIGNAL TO NOISE RATIO (PSNR)

PSNR computes the peak signal-to-noise ratio, in decibels, between two images. PSNR ratio is used as a quality measurement between the original and a newly constructed image. The higher the PSNR, the better is the quality of the reconstructed image. To compute the PSNR, first we have to compute the mean squared error (MSE) using the following equation:

$$MSE=\Sigma M, N\, [I_f(m,n) - I_i(m,n)]^2 / M*N$$

Here M and N are the number of rows and columns in the images to be compared. After the MSE calculation is over, the answer of the MSE is used to compute the PSNR using the following equation:

$$PSNR= 10\log_{10}(R^2/ MSE).$$

In this scenario R is the maximum fluctuation in the input image data type. For example, if the input image has a double-precision floating-point data type, then *R* is 1. If it has an 8-bit unsigned integer data type, *R* is 255, etc.

4. IMPLEMENTATION DETAILS OF THE PROPOSED ALGORITHM

4.1 OBJECTIVES OF THE PROPOSED ALGORITHM

i. To extract all the relevant information from the input sources.

ii. To remove the blurredness from the two input images and reconstruct an image that will provide more detailed and reliable information.

iii. To produce a more efficient representation of the data.

iv. To compress the resultant image so that the space required for its storage will be less.

4.2 PROPOSED ALGORITHM

I. Obtain the two blurred input images (images to be fused) $I_1(x, y)$ and $I_2(x, y)$.

II. The input images $I_1(x, y)$ and $I_2(x, y)$ are arranged in two column vectors and their empirical means are subtracted.

III. In this step the eigenvector and eigenvalues for this resulting vector are computed and the eigenvectors corresponding to the larger eigenvalue is obtained.

IV. The normalized components P_1 and P_2 are computed from the obtained eigen vector using the following equation:

$P_1 = V(1) / \Sigma V$ and $P_2 = V(2) / \Sigma V$

V. The de-blurred fused image is calculated using the following equation:

$$I_f(x,y) = P_1 I_1(x,y) + P_2 I_2(x,y)$$

VI. Lastly, the image quality of the de-blurred fused image is calculated using PSNR by the following equations:

$$MSE = \Sigma M, N\ [I_f(m,n) - I_i(m,n)]^2 / M*N$$

$$PSNR = 10\log_{10}(R^2 / MSE)$$

4.3 SYSTEM DIAGRAM

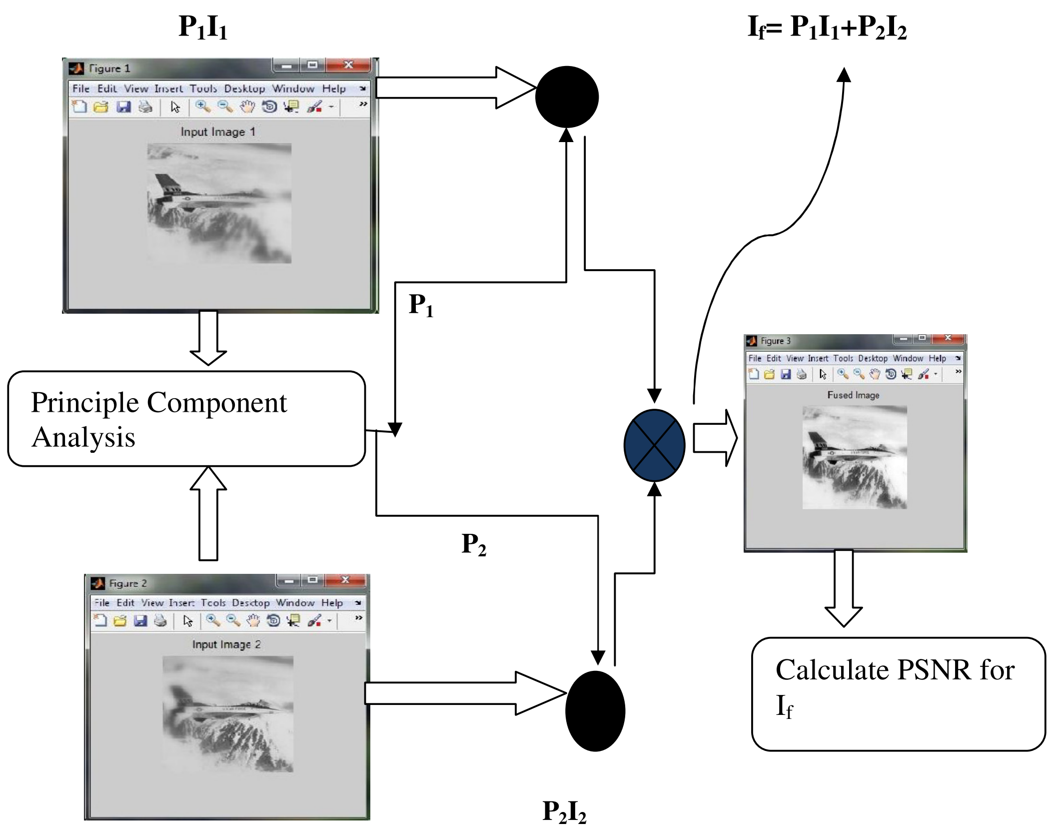


Figure 4.3 : System design of the proposed algorithm

4.3.1 SYSTEM DIAGRAM DESCRIPTION

i) Input images I_1 and I_2:

In the system diagram we see that, first two input images namely I_1 and I_2 are taken. The images I_1 and I_2 are blurred in two different portions. Then the input images are fed in two directions, one to the principal component analysis block and the other to the black colored circles.

ii) Principal Component Analysis block:

In the principal component analysis block a compact and optimal description of the two input images are obtained. Principal Component Analysis involves a mathematical procedure that transforms a number of correlated image variables into a number of uncorrelated image variables called the principal components. Thus the outputs from this block are the principal components P_1 for input image 1 and P_2 for input image 2.

iii) Black colored circles:

After the principal components of the input images are computed and obtained, these principal components namely P_1 for input image 1 and P_2 for input image 2 are fed to the black colored circles. Thus we can say that the black colored circles P_1I_1 and P_2I_2 contain the original pixel values and the principal components of the two images I_1 and I_2 respectively. Here, since P_1I_1 and P_2I_2 are computed, we can perform the image fusion in the next step.

iv) Blue colored circle:

For fusing the two images, here we will simply add P_1I_1 and P_2I_2 and obtain a new reconstructed fused image called I_f.

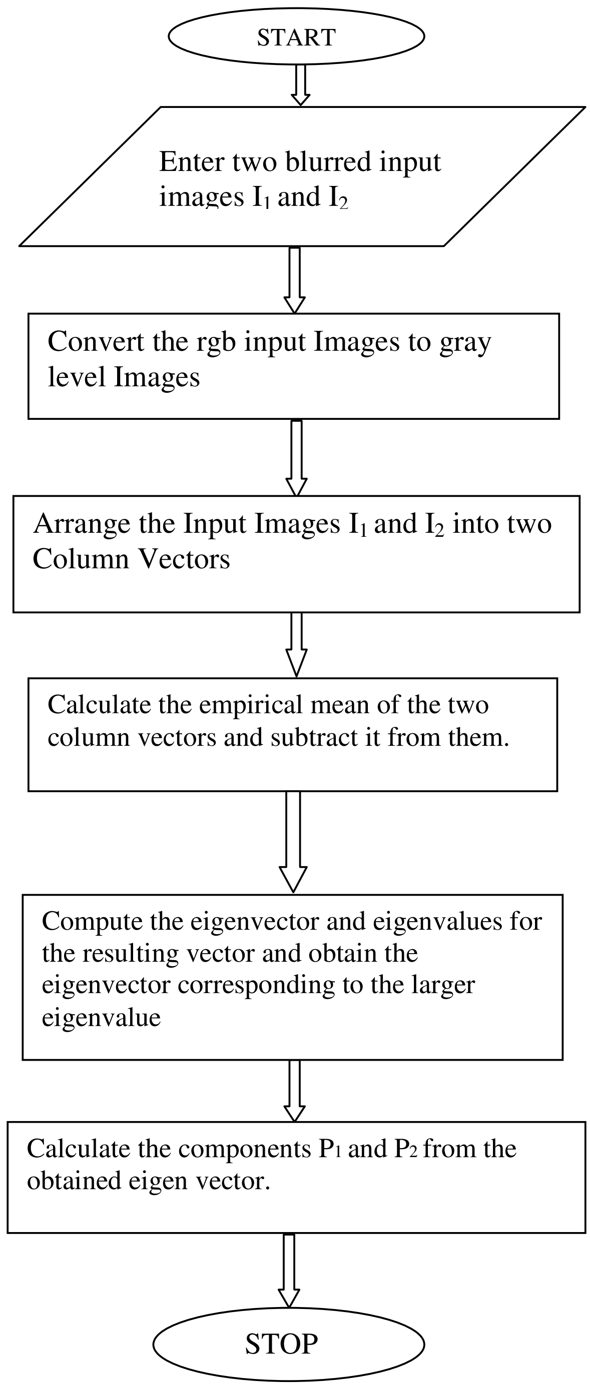
v)Fused image I_f:

The fused image I_f is a de-blurred image, in which almost all the features of the two input images I_1 and I_2 are visible. Lastly, for measuring the quality of the reconstructed image, the fused image I_f is fed to the PSNR block in the next step.

vi) PSNR block:

PSNR stands for peak Signal to noise Ratio. PSNR computes the peak signal-to-noise ratio, in decibels, between two images. This ratio is used as a quality measurement between the input image and a fused image. The higher the PSNR, the better is the quality of the reconstructed fused image. We will calculate the PSNR of the fused image I_f with respect to the two input images I_1 and I_2. We will also calculate the PSNR between the two input images I_1 and I_2 so that we can understand whether the quality of I_f is better or no.

4.4 WORKFLOW DIAGRAM



4.5 DATABASE DESCRIPTION

The image database is divided into 4 parts:

- Human face database

- Object database
- Scenery database and
- Standard test images database

The database contains a total number of 336 images. All the images in this database are of type .jpeg and the total size of this database is 6.43 MB and is able to handle complicacies of the proposed algorithm.

4.5.1 Human face database:

This database contains 100 human face images with variations in the blurredness of the images. These 100 images are obtained from 50 different people. All the images are of size 256x192 pixels and are taken under controlled condition. The database contains 15 upside blurred, 15 down side blurred, 35 left-side blurred and 35 right-side blurred images. The size of this database is 748 KB.

Figure 4.5.1 : Sample images from the human face database

4.5.2 Object database:

This database contains 120 object images with variations in the blurredness of the images. These 120 images are obtained from 60 different objects. All the images are of size 256x192pixels and are taken under controlled condition. The database contains 10 upside blurred, 10 down side blurred, 50 left-side blurred and 50 right-side blurred images. The size of this database is 2.64 MB.

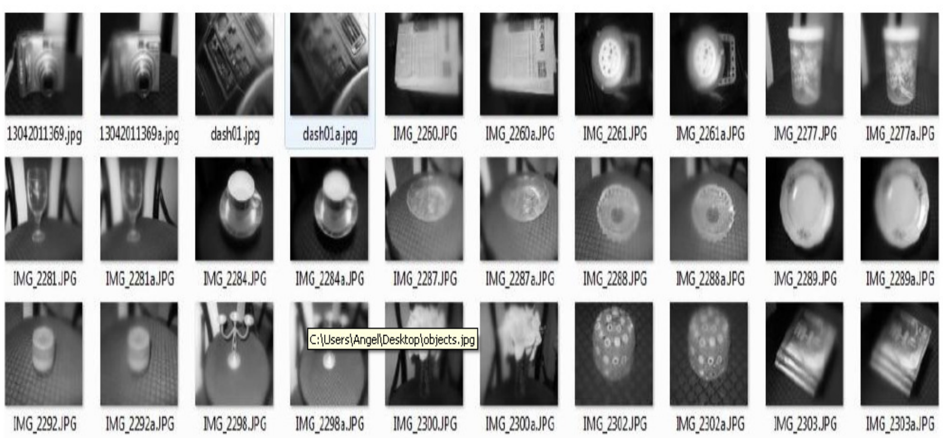


Figure 4.5.2: Sample images from the object database

4.5.3 Scenery database:

This database contains 100 scenery images with variations in the blurredness of the images. These 100 images are obtained from 50 different sceneries. All the images are of size 256x192 pixels and are taken under controlled condition. The database contains 8 upside blurred, 8 down side blurred, 42 left-side blurred and 42 right-side blurred images. The size of this database is 2.30 MB.

Figure 4.5.3 : Sample images from the scenery database

4.5.4 Standard test image database:

This database contains 16 standard test images that are being downloaded from the internet, with variations in the blurredness of the images. These 16 images are obtained from a combination of 8 different object, human face and scenery. All the images are of size 256x256 pixels and are taken under controlled condition. The database contains 1 upside blurred, 1 down-side blurred, 1 not blurred, 1 full blurred, 6 left-side blurred and 6 right-side blurred images. The size of this database is 524 KB.

Figure 4.5.4 : Sample images from the standard test image database

4.6 ADVANTAGES OF THE PROPOSED ALGORITHM

I. *The algorithm will compress the image, thus the space required to store the image will be less.*

II. *The resultant or fused image is visually more illuminated than the two input images.*

III. *As the minimum number of PCA components will be chosen for fusion instead of whole components, therefore there will be higher accuracy.*

IV. *PCA based fusion algorithm is relatively simple and time efficient fusion scheme so the time required to execute the program will also be very less.*

V. *The algorithm has lower complexity.*

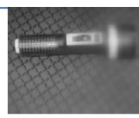
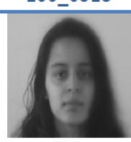
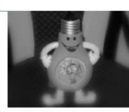
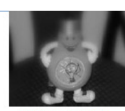
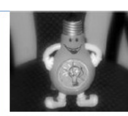
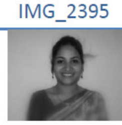
4.7 SIMULATION

We have used the MATLAB Version 7.8.0.347 (R2009a) for the completion of our project. MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Our algorithm mainly based on Principal Component Analysis. Principal component analysis (PCA) involves a mathematical procedure that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables called *principal components*. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. The main objectives of principal component analysis are to discover or to reduce the dimensionality of the data set and to identify new meaningful underlying variables.

The simulated study that was conducted to evaluate the relative performance of the proposed algorithm which is based on PCA. The simulation was carried out for 50 de-blurred fusion samples. Thus, 100 images in total were involved for obtaining the output of 50 de-blurred fusion samples. The detailed experimental results are tabulated below in the performance analysis portion. There are two tables for displaying the results, one for showing the PSNR values and the other for showing the estimated time required for each set of image fusion. For simulation we have used our own database which contains a total number of 336 images. The database is divided into four parts namely Human faces, Objects, Sceneries and Standard test images. All the images in this database are of type .jpeg and the total size of this database is 6.43 MB and is able to handle complicacies of the algorithm. This algorithm can operate on blurredness present in any portion of the two input images.

4.8 PERFORMANCE ANALYSIS

We also see that the proposed algorithm is very time efficient as the estimated time was within 3 seconds for all the set of fused images. The PSNR values of all the fused images with respect to their corresponding input images are also comparatively higher. The detailed experimental results are tabulated below in the two tables namely: Table1- Peak Signal to Noise Ratio of the Fused Image w.r.t the two input images (50 fusion samples) and Table 2-Estimated time for image fusion (50 fusion samples).

Exp. No.	Input image 1 (Right side/ Down Blurred)	Input image 2 (Left side / Up Blurred)	Fused Image	PSNR between the input images (in decibels)	PSNR of Fused Image w.r.t Input image 1(in decibels)	PSNR of Fused Image w.r.t Input image 2 (in decibels)
1.	 IMG_2397	 IMG_2397a	 IMG_2397out	24.6796	29.4975	30.3617
2.	 IMG_2391	 IMG_2391a	 IMG_2391out	23.8575	29.6132	29.9311
3.	 IMG_2392	 IMG_2392a	 IMG_2392out	24.5910	29.6231	30.2353
4.	 100_0318	 100_0318a	 100_0318out	25.4273	31.3794	31.4625
5.	 f54	 f54a	 f54out	31.7978	37.1746	37.6369
6.	 IMG_2395	 IMG_2395a	 IMG_2395out	25.3329	31.3356	31.2859
7.	 IMG_0100	 IMG_0100a	 IMG_0100out	30.4721	36.4400	36.3734
8.	 IMG_2388	 IMG_2388a	 IMG_2388out	23.1742	28.6062	28.5788
9.	 f91	 f91a	 f91out	32.5094	38.1368	38.2094

Exp. No.	Input image 1 (Right side/ Down Blurred)	Input image 2 (Left side / Up Blurred)	Fused Image	PSNR between the input images (in decibels)	PSNR of Fused Image w.r.t Input image 1 (in decibels)	PSNR of Fused Image w.r.t Input image 2 (in decibels)
10.	 Picture 025	 Picture 025a	 Picture 025out	23.8216	27.7636	27.9515
11.	 digi cam 054	 digi cam 054a	 digi cam 054out	24.4822	30.3396	30.2989

Table 4.8: Peak Signal to Noise Ratio of the Fused Image w.r.t the two input images (50 fusion samples).

5. CONCLUSION

Considering the various set of blurred input images and the de-blurred fused results, we come to conclude that the proposed algorithm for image fusion using Principal Component Analysis produces a comparatively better quality fused de-blurred image. Principal Component Analysis is a mathematical procedure that transforms a number of correlated variables into a number of uncorrelated variables called principal components. PCA computes a compact and optimal description of the data set. The PCA does not have a fixed set of basis vectors like FFT, DCT and wavelet etc. [16] and its basis vectors depend on the data set. We also see that the resultant images are more illuminated and require less amount of space for storage. Since, the proposed algorithm is based on PCA we see that the algorithm has lower complexity and is very time efficient because the estimated time is within 3 seconds. The PSNR values of all the fused images with respect to their corresponding input images are higher. Our algorithm has mainly four parts:

a. Taking the two images I_1 and I_2 as inputs.
b. Principal Component analysis of I_1 and I_2.
c. Multiplying the input images with the principal components.
d. Calculating the Fused Image using the proposed formula.

6. FUTURE WORK

In future, we plan to fuse more than two images and produce a de-blurred fused image. We also plan to concentrate on increasing the PSNR value of the fused image as compared to the current PSNR value, as we know that more the value of the PSNR the better is the quality of the image.

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