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Study of Intelligence and Enhanced Techniques of Data Fusion using Constitutional Neural Networks (CNNs) and Principal Component Analysis (PCA)

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Abstract: — Image fusion refers to a wide class of data processing methods that attempt to pool information from many images taken with the same or different spectroscopic instruments or on different platforms. Both regression models that link seemingly unrelated photos or the construction of a single multiset or multiway structure can be used for image fusion, data analysis based on the structures of fused images always trumps the results of individual picture analysis.Image fusion can be employed in many different situations and for many different reasons, such as the characterization of components in 3D hyperspectral images or in sets of linked 2D photos. An image is a representation of a real-world item or person created by optical (such as a lens or mirror) or electronic means.In this study, we examine the use of principal component analysis with convolution neural networks for the purpose of multi-resolution picture fusion.in this research reveals that PCA and CNN both have their benefits and drawbacks. Despite being the most elementary approach to image fusion, principal component analysis (PCA) has been shown to be the least efficient in our studies. Convolutional neural networks (CNNs), on the other hand, are effective but challenging to maintain and may produce merged images with mismatched, unrecognizable boundary pixels.

The results are analyzed using a number of statistical measures of image quality.

Keywords: *CNN, Image Fusion, IQA, Multi-focus image fusion, Mean Square Error, PCA, PSNR, SNR*

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1. Introduction

The term "image" comes from the Latin word "Imago," which means "image, the Latin word for "image" also means "to copy," which is whence we get our word "Imago." In other words, a "picture" is only a snapshot of the present. Photographs are frequently used to document events for subsequent memory, After Nicephore Niepce's invention of photography in the mid-1820s, several scientists worked to improve the technique and associated technologies [1,2,3].

The number of possible applications for electronic devices is growing exponentially as they become more commonplace in daily life. Photos are more significant than ever, especially to today's youth who want to document their every move through the use of mobile devices.

Digital photography has entered the mainstream thanks to the accessibility of digital cameras and the convenience of camera phones. Although the low cost of these tools, even people living in remote areas are beginning to document their surroundings through photography.

This has led to an increase in the number of photographs taken and published online, while representations of a subject already exist in the physical world. Two-dimensional (2D) and three-dimensional (3D) images are distinguished by the number of frames captured and the precision with which they are projected. While many images projected from various angles preserve the integrity of a three-dimensional image, the opposite is true for two-dimensional images. In this context, "fusion" refers to a method for compiling information from several sources, By

merging information from several sources (including multiple sensors, numerous times, and/or multiple viewpoints), the goal of the image fusion process is to produce a new, ideal image. In different contexts, the standard may serve different purposes and be evaluated in different ways, A low-quality, low-resolution image will not have enough information to properly describe its topic, and this can vary depending on the camera used to acquire the image[4,5]. One solution could be to combine two separate photos into a single, more useful one by using information from both sources.

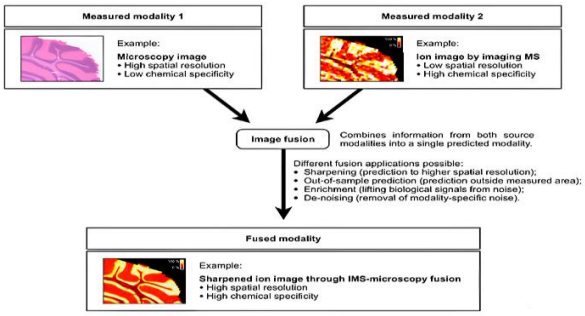


Fig 2: Image Fusion Example

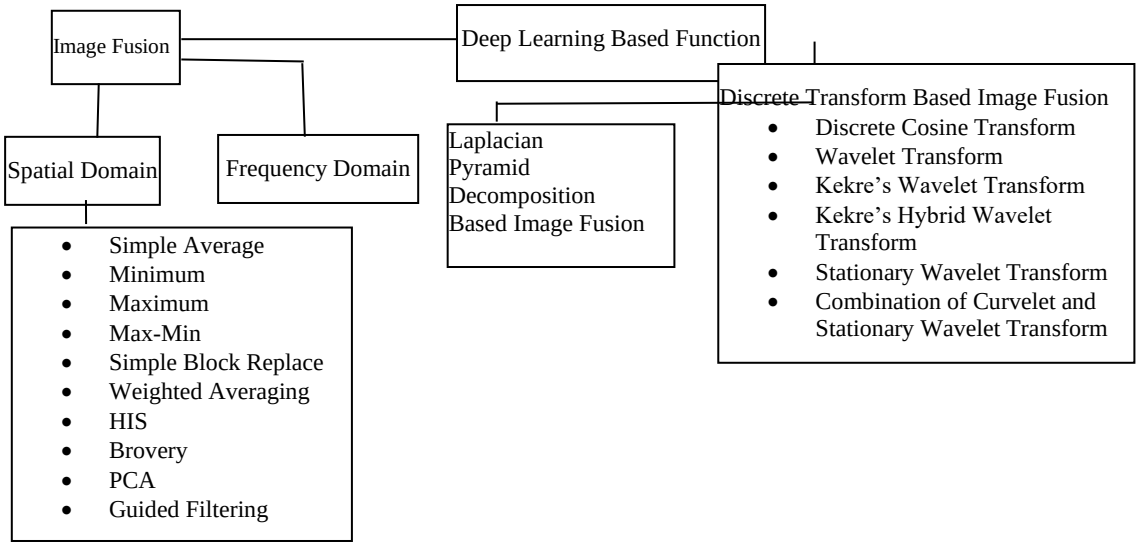


Fig 1. Simple image fusion process

Data fusion allows for the processing of photographs without forcing the analyst to choose between keeping spectral integrity and fine detail, portrayed as the process of breaking up large groups of photos into a smaller and larger number of individual pictures (through some fusion settings based on the image attribute). All the relevant information is here, in sequential order, Picture fusion's goal is to lessen the quantity of data that must be stored by making images that are easier for both humans and computers to understand. Essentially, we combine the best features of data from multiple photos of the same scene to produce a new image. The success of picture fusion relies on the closeness of input images in terms of shape and features, While fusing photos together, pay attention to the clarity of the final product. There is a significant variation in the quality and resolution of the entering image datasets. High spectral and spatial resolution are essential in many image processing uses, no current resource is available to reliably offer such information without evoking counter examples[6,7,8]. Combining data from many sources is made possible by image fusion methods, both the spatial and spectral resolutions of the image can be improved by working together. When integrating multi spectral data, traditional picture fusion methods can cause distortions to the spectrum information.

two types of images used in satellite imaging, while multi spectral imaging is commonly employed at lower resolutions, the panchromatic image from satellites is routinely distributed at the maximum resolution. That would normally be 1.5–3 times that amount. Image fusion can be accomplished in numerous ways, it comes to filtering, high-pass is the way to go in almost every situation. The Laplacian pyramid, rational filter fields, and discrete wavelet transforms all form the foundation for additional methods. Picture fusion is a method for producing a single photograph that is more detailed and accurate than the sum of its source photographs. The following functions should be handled with the most suitable picture fusion technique, it will keep a lot of information from the many pictures [9-11]. Also, it can't fool human observers or other image processing systems with its outputs, Second, it must be reasonable to believe that, Finally, it is important not to disregard an input image if it contains useful information.

Multi resolution Image Fusion

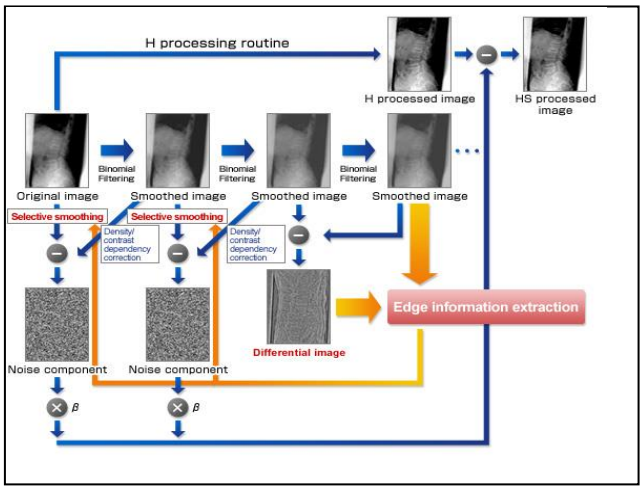


Fig 3. Multi resolution Image Fusion[13].

Digitally combining data from multiple images into one single file is known as "multi resolution picture fusion." Many different image fusion techniques have emerged as a result of the increasing popularity of using satellite-based sensors for remote sensing. It is challenging to take a picture with everything "in focus" because of the limited focal range of optical lenses[13,14,16]. The focus depth of a camera refers to the apparent distance range within which subjects can be captured in sharp focus. To circumvent this, you can combine the sharpest parts of multiple photographs shot at varied focus lengths into a single, high-quality composite, The method employed to capture the images contributes to their low resolution. Out-of-focus and diffraction-limit issues may lower the quality of the lens subsystem and optical sensors used in this process. Optical aberration and atmospheric turbulence are two examples of conditions that might amplify distortion. The final image quality is also affected by the shutter speed and the distance between the camera and the subject. Down-sampling causes aliasing and other image quality issues in practice, mathematically modeling the process of image acquisition, we can get insight into the picture reconstruction problem. Academic theory can be used in the real world through the forward or observational model (s). Any visual re-enactment technique relies heavily on the precision of the observation model. Forward models frequently include elements like translation, blurring, aliasing, and noise[18,19]. The MS image with the lowest spatial decision is used as a basis by image fusion techniques to reconstruct the MS image with the highest spatial decision. Both MS images suffer from aliasing because their sampling rate is less than the Nyquist frequency. The first estimate is derived by working backwards from the experimental data. This provides a streamlined model of the inverse problem. The inverse problem can be solved by inverting the forward transformation. More questions arise than answers, and there may be more than one way to solve this one. This makes it challenging to invert the forward model without introducing noise into the observed data. Posed inverse problems arise because of these difficulties, High-resolution (HR) to low-resolution (LR) transformation, a forward model for the multi-resolution fusion problem, can be reduced to matrix operations. Matrix inversion makes intuitive sense as a model for the fusion problem in the context of restoration, it’s not enough to put your best foot forward and hope for the best. The number of viable options should be restricted. When perverse evils are switched around, a process known as "regularization" is employed to guarantee internal consistency. Regularization-based methods use the available information to provide better solutions to poorly-posed inverse evils, hence explaining their presence. It's a plan for methodically expanding the modernisation infrastructure over time. Often used to solve such issues, Bayesian re-enactment is now within reach, this line of thinking becomes irrelevant once it is established that a specific probability exists for the fictitious scenario under consideration. A priori reproduction is used to classify results in Bayesian estimation for fused images[20.21,23]. The Bayesian technique is superior to other ways due to its a priori grasp of the explanation and solution via optimization methods, as well as its heaviness and digestibility in expressing dining-out factors. In place of computationally expensive methods like simulated annealing, efficient and proficient ramp-based procedures can be employed to build the mixture for curved optimization.

2. Literature Review

Amit Rai et al. (2020) Using an image fusion technique, we categorised multi-spectral satellite images captured by Landsat 8's OLI, in the research, three different image fusion techniques were used. First, we used the Brovey approach to fuse the original image's RGB bands, then we utilized principal component analysis to reduce the number of dimensions, and finally, we used a convolutional neural network to classify the different land cover categories. FCM, GIFP-FCM, and FKLICM were all fed the outcomes of these processes to evaluate and compare. Many measures of precision, including the kappa coefficient, were applied to the findings.

Naranjo-Torres et al. (2020) Provides introductory, illustrative tools and material, The results of this study show that Convolutional Neural Networks (CNNs) have been very effective in the previous two years for various automatic procedures, including quality control, detection, and categorization of various fruit photos. In their analysis of various image fusion techniques, Navita et al.(2018) discovered that each technique has both benefits and drawbacks. According to the review, utilizing fusion techniques as a whole yields superior outcomes to utilizing them singly or in isolation[24,26].

Patil et al. (2011) presented a hybrid of principle component analysis and the pyramid fusion technique to improve picture fusion quality; they dubbed it hierarchical PCA. We then evaluate the proposed approach in relation to the principal component analysis, the pyramid, and the wavelets approaches. Many quantitative and qualitative metrics are employed for comparison, including the standard deviation (SD), standardized standard error of the mean (SSIM), variance (VI), standard fortune (SF), mean (MI), mean (CE), and quality (QM1, QM2). Data from cameras of different sizes, focal lengths, and modalities are used in the analysis, The results show that the hierarchical approach performed better than using PCA, Pyramid, or a wavelet-based fusion algorithm alone. PCA, DWT, and DCT based image fusion approaches were examined by Rajendra et al. (2013), who drew up and studied their algorithm, process flow diagrams, and conceptual underpinnings. A comparison reveals that the DWT fusion method is superior to both the DCT and PCA approaches. A variety of quality measurements, including PSNR, MSE, MD, NAE, AD, NCC, and SC, are utilized to do this.

Hamid et al. (2012)proposed a new fusion strategy to enhance the common PCA approach, Principal component analysis (PCA) is one way to improve multi spectral images, however the proposed method improves both spectral and spatial information because it operates on image blocks made of pixels. The quality indicators used in this research were CC, ERGAS, UIQI, SAM, and Q4.Based on the results of these quality indicators, the proposed approach is determined to be more quality-preserving than the standard PCA, Bravery, HIS, HPM, and HPF.

Kusum et al. (2013)the many methods of image fusion were analyzed and compared; some of the methods included principal component analysis, discrete wavelet transform, simple minimum, simple average, and simple maximum. The results show that spatial fusion offers superior spatial resolution but suffers from internal blurring, whereas wavelet fusion yields superior spectrum content. The study author recommends combining PCA with the DWT method for optimal results.

Yang et al. (2017) developed a new fusion technique by combining NSCT with SR, The source images are deconstructed using NSCT to get a single low-pass sub image and several high-pass sub images. The low-pass sub images are then fused using the SR fusion technique. Scientists came up with a plan based on MSMF, The research incorporates both qualitative and quantitative techniques to show how the recommended strategy outperforms the alternatives. Vibha et al. (2016) compared and contrasted various picture fusion techniques and certain quality assessment criteria, The results indicate that it is more effective to combine qualitative and quantitative approaches into a single analysis than to use either approach separately. In this comprehensive guide, you'll find in-depth evaluations of the many different methods for fusing images, broken down by category and categorized by their relative strengths, shortcomings, and future prospects. .

T. jayasindhuri et al.(2014) adds principal component analysis (PCA) to the output of DT-CWT (Dual Tree Complex Wavelet Transform), increasing its quality. Principal component analysis (PCA) was used to compare the output of DT-CWT with DT-CWT combined with PCA, and it was revealed that the latter produced greater results and information gain.

Xudong et al. (2017)In this paper, we offer a PCA-based Edge preserving features technique for the classification of hyper spectral images. Images from many sources of hyper spectral data were run through a series of standard edge preserving filters (EPFs) with a range of parameter values, and the resulting EPFs were collected for dimensional reduction via principal components analysis (PCA). Mean square plots are then used to show the pixel separability present in each EPF. The information is then passed on to a Support Vector Machine based classifier once PCA-EPF has been performed (SVM). This study demonstrates that improving SVM quality and accuracy by integrating PCA and EPF.

Amita et al. (2018)A modified LWT-PCA methodology is offered to merged source images in an effort to combine the advantages of the frequency domain fusion method with the spatial domain fusion method while avoiding their disadvantages. Final image retrieval made use of inverse principal component analysis, Using these standards, we compared LWT, LWT-PCA, DWT, and DWT-PCA, the results show that the alternative approach is superior.

Li Yuan et al. (2019)In this research, a wavelet was used to combine high- and low-frequency components by allowing for multi-scale customisation of both the input and output images. The low and high frequency pictures in the original and final data are precisely aligned using a robust CNN, resulting in a more informative and clear fused image, The convolution networks are studied using both high- and low-frequency pictures. According to the researcher, his experiments back up his claim that his proposed method has a good chance of achieving a fused image that is superior and better across several evaluation criteria.

Bosse et al. (2018) IQA configurations, complete and no-reference implementations, and connected learning of local quality and local weights are just a few of the ground-breaking characteristics revealed in his research into the use of deep neural networks for assessing image quality. The outcomes of the experiment were calculated using the 2013 versions of LIVE, CISQ, and TID.

Deepak Kumar Sahu et al. (2012) explored numerous methods for combining images, including ones that use Discrete Wavelet Transforms, Principal Component Analysis, and others. The provided results suggest that spatial domain image fusion not only delivers high spatial resolution, but also addresses the problem of image confusion. The DWT is a helpful method for picture fusion due to the finer spectral content it provides. Although the final image must have both attributes, the author asserts that using the DWT and spatial domain fusion technique together increases process performance over using the DWT and PCA algorithm alone.

Nahvi, N et al. (2014) Explain how to use the DWT method to a collection of images to produce a single output that contains practically all the required details, Not only are PCA, HIS, and HPF mentioned, but also a number of others. Using methods like pixel averaging, min-max, and max-min fusion, researchers have provided a novel approach for clinical picture fusion.

Bedi, S. et al. (2013) Image fusion techniques such as the discrete wavelet transform (DWT) and the pyramid fusion approach will be discussed. Gives background on the development of various common fusion techniques used today (including primitive, DWT, PCA-based fusion, and others). The research provides extensive detail on a wide range of calculations and their comparative analysis.

Huang, W. et al. (2007) demonstrated an innovative PCNN-based multi-center image fusion approach. One measure of an image array's clarity is its picture Laplacian power, An untrained PCNN is the secret to the success of the proposed method, The study's author developed a recursive procedure to filter out false positives. Several iterations are used by researchers to hone their findings. The experimental findings prove the superiority of the proposed method over the DWT approach and Li's and Miao's methods.

Dhivya, R. et al. (2017) An technique based on fuzzy logic was developed to detect image boundaries without using a hard threshold, First, a series of 3x3 matrices chosen at random is used to articulate a visual. The proposed procedure reliably yields the desired results when applied in the ways you outline, Due to its high PSNR and low MSE values, this adaptive filtering strategy outperforms state-of-the-art strategies for noise reduction [52-53].

Sweta K. et al. (March 2014) SWT's implementations in the spatial and transform domains show that it is superior to PCA and DWT for fusing pictures. In a comprehensive study of how different contrast enhancement techniques affect the separation of color images, BORA, D. J. (2017) draws some interesting conclusions. Even when noise is present, when it comes to

improving color pictures and segmenting color images. By looking at the available experimental data, we may conclude that the HSV color space allows BSB-CLAHE to perform better than previously thought when segmenting color images [34,35,36].(Vijayan & Sreeram.S, 2015) Of the many ways for fusing images that have been discussed, as particularly useful options. When comparing DWT, Laplacian, SVM, HOSVD, and Guided filtering as methods for image fusion, the latter stands out as the superior option. Decomposition at various scales, color distortion, and issues related to fused output lighting are all addressed via filter-based picture fusion. However, directed filter has the drawback of being more time-consuming to implement. When it comes to filtering images, LEP is also more effective than a guided filter. By substituting LEP image fusion filters for directed fusion filters, the guided fusion-based filtering can be improved [31,37].

Kangjian; Zhou, Dongming; Zhang, Xuejie; Nie, Rencan; 2018 Proposed a new multi-scale IR and VI picture merging scheme focused on alluring region detection capable of adding more context information as well as highlighting the interesting field with the notable objects. This approach merges various advantages of the directed Mean Shift and filter. The history regions are then fused within the NSCT domain. To fuse the low-frequency layers, an enhanced weighted average method based on the weighted average per pixel is used, and the SF-PCNN-based method is used to create the new fused layers for the high-frequency layers [31,32,33]. Jamal Saeedi et al. (2011) presented a new wavelet-based method for fusion of images. Two class classification process is used by the researcher for the formulation of problem. In the first-class Dual tree- DWT is used for the extraction of sub bands of the source image and then in the second class a class labeling is being done by Fisher classifier. The output generated by the classification process is then used for the fusion of wavelet coefficient of high frequency for all the source images and generate a decision map for it. But there is some classifications of pixels due to uncertainty of selecting high frequency pixels. To resolve this problem researcher used a fuzzy logic based approach and fuse both low and high frequency data[52-53]. Yong Yang et al. (2016) presented a novel multi focus image fusion technique, used NSCT and proposed fuzzy logic based adaptive PCNN for the development by calculating sum- modified Laplacian. Characteristics of human visual perception is considered for developing fuzzy logic to different frequency sub bands. Proposed method is then proved to be more effective and efficient than other fusion techniques [50-51].

3. Methodology

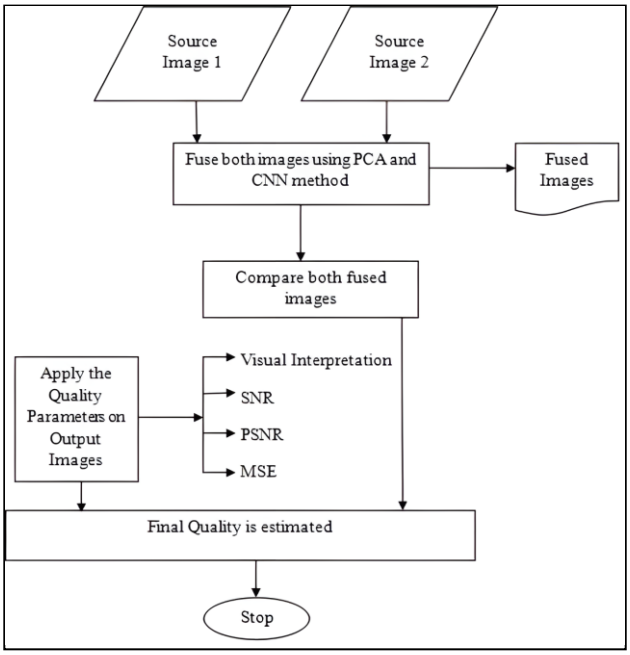


Fig 4. Applied Methodology

Image fusion, intent at exploiting corresponding information in multi-resolution images to construct a specific composite image with enhanced or amplified in order content. Source images taken for fusion purpose must be of same size, PCA and CNN algorithm is then applied separately on the source image, that can be used for further analysis instead of the original multi spectral one. It unbiased reveals the internal data structure [6,7,8,9].

PCA algorithm is as follows:

a. Settle the data into column vector of 2*n.
b. Pick all the possible principal components of the multi-spectral band.
c. Calculate the covariance of vector matrix.
d. Calculate Eigenvector and Eigen values.
e. Choose the highest covariance and first principal component is taken along with it.
f. All the following principal components lie in the subspace of prior PC.

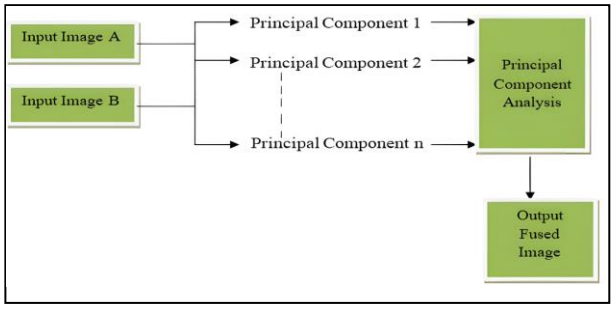


Fig 5. PCA Image Fusion

CNN is basically a method that is used for the decision making in critical image related issues by focusing and extracting high level feature and frequency details of the source images and then provides a concluded, final picture giving decision about the information used in images[37-39].

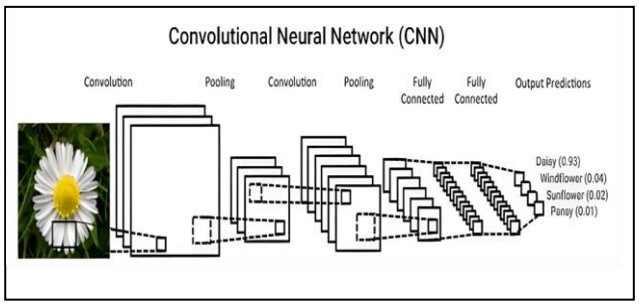


Fig 6. Layered Architecture of Convolution Neural Network

Algorithm for CNN image fusion is:

a. Chosen source image must be identical in size.

b. Input images then first fed into convolution layer: Convolution layer contain filters for initial filtering of source images.

c. Convolution output is then fed into pooling layer: pooling layer is then reducing the dimension size produced by convolution layer and also used to calculate position parameters by using pooling functions such as max pooling, min pooling, mean pooling.

d. Output of pooling layer is the forward to Fully Connected layer: This layer is then classifying the images into features for digital vision and then these images are analyzed separately.

At last, the output is processed by Soft max function: This function also known as normalization function that takes input from the fully connected layer and normalize the input components into probability components that lies within the interval (0,1)[40-41].

Fig.	SNR (PCA)	SNR (CNN)
Fig 1	12.9182	12.4172
Fig 2	12.7429	11.1904
Fig 3	15.3511	13.7077
Fig 4	13.6876	13.4155
Fig 5	13.7549	13.4299

Table 1: Statistical Calculation of SNR by PCA and CNN

4. Quality Assessment

Quality assessment is the data collection and examination through which the scale of conformity to destined standards and criteria are elucidated. Four classes of image quality assessment (IQA) algorithms are discussed in this paper— Visual Interpretation, SNR, Peak-SNR and MSE. Each of these techniques approaches the IQA problem from a different frame of reference and using different initial principles[32-33].

a. Visual Interpretation

As per prior assessment rules or individual judgment or even evaluation realize that how to be certain to the eminence of image. The interpreter investigates the differentiation, immersion, sharpness and texture of the final fused image. It is effortless to infer however depends enormously upon information on spectator and cannot be represented by a mathematical model[42-48].

b. SNR- Signal to Noise Ratio

SNR is the amount of sign quality comparative with added noise. It is generally estimated in decibels (dB). If the noise and signal strength are in micro volts is Vs and Vn respectively then the SNR is calculated using the below mentioned formula:

If Vs = Vn then SNR = 0

i. It is the ideal condition where, if Vs > Vn, high SNR is positive.

ii. If Vs < Vn , low SNR is negative.

c. PSNR- Peak Signal to Noise Ratio

PSNR is used to compute the peak SNR between two images; it is also calculated in decibels. Quality of final image is directly proportional to the PSNR value, if the PSNR value is high, the quality of final image also hikes or vice versa. To calculate the PSNR value, first have to calculate MSE from the given formula:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[T(i,j) - K(i,j)]^2$$

Here in the equation: M and N are the number of rows and columns in the source images.

PSNR is then calculated, R is the highest deviation in the source image[44-50].

d. Mean Square Error

MSE is the comparison parameter to determine the quality of image. It represents the aggregate squared error between the two images. MSE plays a vital role in the calculation of PSNR value. MSE value is directly proportional to the error presents in the image. The less is the MSE the less is the error. Lower MSE value represents the high-quality image.

5. Experimental Setup

Experiment is performed on 5 image block of different sizes. In all the 5 blocks of images two images of the same block are having different blur parts. For the purpose of comparison, evaluation is performed on the fused images with the help of above-mentioned quality assessment parameters.

Following Fig. 7 shows the fusion of input images into single fused output image having all the informative parts that are not blur visually. Table 1 exhibits the SNR values for all the 5-image block using both PCA and CNN individually.

Graph 1. Statistical Calculation of SNR by PCA and CNN.

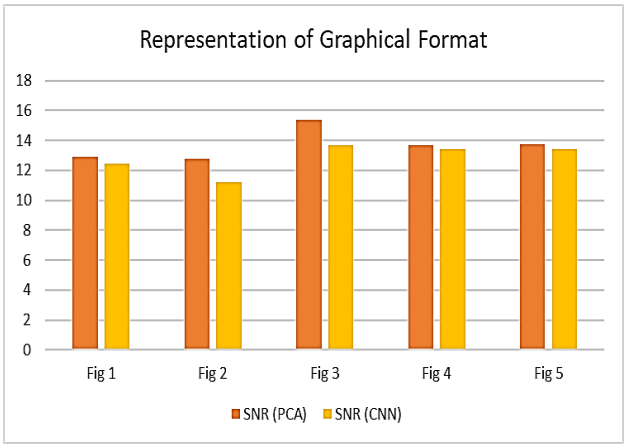


Fig. 8: Statistical Calculation of SNR by PCA and CNN

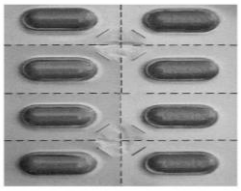
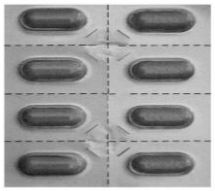
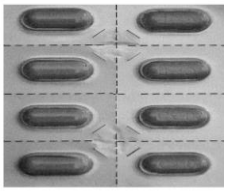
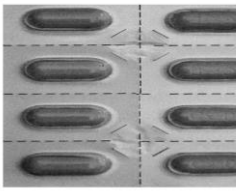
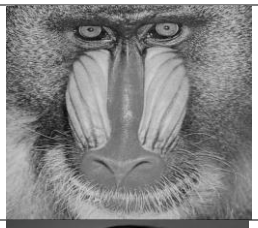
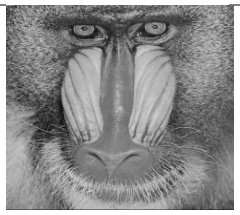
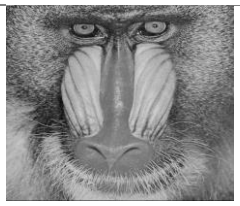
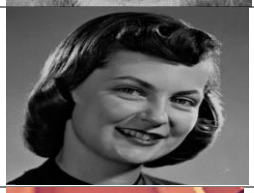
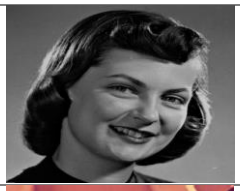
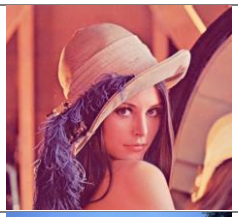
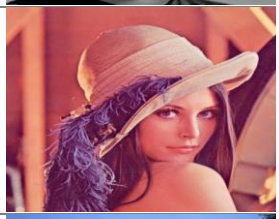
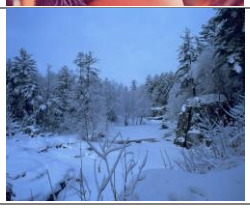
Sr. Number	Input Data		Convolution Neural Network Output	Principal Component Analysis Output
1				
2				
3				
6				
7				

Fig 7. Modality Internal representation of Results by PCA and CNN

Table 2: Statistical Calculation of PSNR by PCA and CNN

Fig.	PSNR (PCA)	PSNR (CNN)
Fig 1	19.6003	19.8636
Fig 2	18.7594	18.8043
Fig 3	18.6279	18.6695
Fig 4	18.6046	18.7011
Fig 5	18.7171	18.7241

Table 2 shows the PSNR values for all the 5-image block using both PCA and CNN individually. Graph 2. Statistical Calculation of SNR by PCA and CNN.

Table 3: Statistical Calculation of MSE by PCA and CNN

Fig.	MSE (PCA)	MSE (CNN)
Fig 1	75.4080	77.7141
Fig 2	72.0299	76.1038
Fig 3	59.4294	63.2296
Fig 4	69.1780	71.9204
Fig 5	68.7210	70.6102

5.1. Types of Graphics

5.1.1. Color/Grayscale figures

Figures that are meant to appear in color, or shades of black/gray. Such figures may include photographs, illustrations, multicolor graphs, and flowcharts.

5.1.2. Line Art figures

Figures that are composed of only black lines and shapes. These figures should have no shades or half-tones of gray, only black

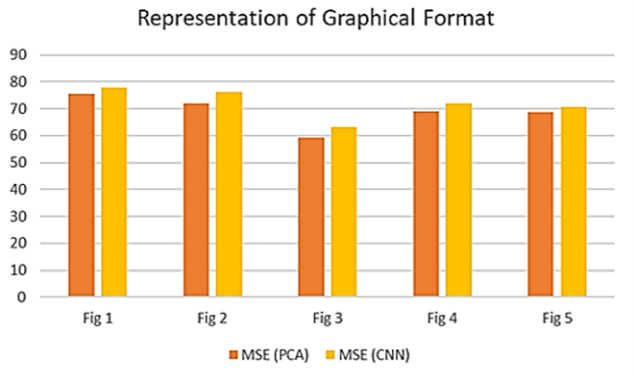


Fig 9. Statistical Calculation of SNR by PCA and CNN

Table 3 shows the MSE values for the entire 5 image block using both PCA and CNN individually. Graph3. Statistical Calculation of SNR by PCA and CNN

6. Results

Fusion results on PCA and CNN are shown in Table 1. After examining both the source and fused images a clear result is can be seen. In the comparison beside visual observation all the statistical parameters like SNR, PSNR and MSE shows different mathematical values for all the five image blocks.

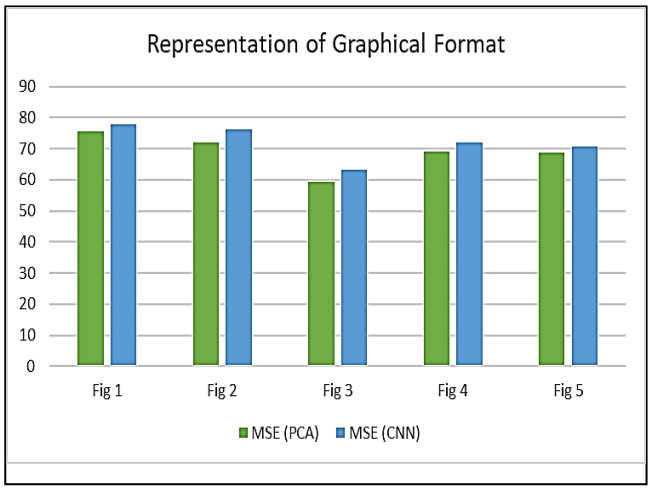


Fig 10. Analysis of Result SNR, PSNR and MSE

6 Conclusion And Future Scope

Image fusion is trending nowadays in every domain in our day-to-day life After experimenting with the PCA and CNN fusion Techniques with different images it demonstrates that the result produced by CNN is more informative and smoother than PCA but the time consumption and cost are very high, also there are some issues on the boundaries of fused images of CNN there present some unrecognized boundary pixels that needs to be fixed in the future along with some time managing algorithms. PCA being simple and less time consuming has some blurring problem hence, must be some quality enhancement technique for PCA in future work.

Conflicts of interest

The authors declare no conflicts of interest.

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