International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2024.0301
e ISSN: 2584-2854
Volume: 02
Issue: 06 June 2024
Page No: 2044-2053

Image Fusion of Multi-Temporal Images of Eyes Feature using Hybrid Approach of PCA and SWT

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Abstract

A wide variety of information is represented by an image feature, which may be applied in various applications such as mage fusion, video processing, medical diagnosis, traffic safety monitoring, visual surveillance, feature matching, image segmentation, pattern matching, person identification, sentiment analysis, human computer interaction and many more fields. This paper focused on multi-temporal feature extraction of eyes feature from human face images captured in two different time slots to reduce the semantic gap from images and to improve the image quality by image fusion using PCA, SWT and hybrid approach of PCA and SWT algorithm. In this paper, comparative study of multi-temporal image fusion using Principle Component Analysis (PCA), Stationary Wavelet Transform (SWT) algorithms and hybrid approach of PCA and SWT are employed and its experimental results are evaluated with its performance analysis. Image fusion performance is compared based on eight quantitative quality measures as SSIM, MSE, NAE, CC , SC , AD, SD and MI.The outcomes of comparison show that employing the hybrid approach of PCA+SWT transform can improve image fusion performance. The applicability of this work approach may have several uses when the utilization of human facial features is feasible.

Keywords: *Feature Extraction; Semantic Gap, Image Fusion*

1. Introduction

An image is a vast source of information that precisely represented by features which represents distinguishing characteristics of an image containing behavior of an image in the form of texture, density, color, shape and brightness inside the image. These feature categorizes under the type of pixel level feature, domain specific features, local features and global feature of an image. Therefore, identification of accurate feature and extraction of appropriate feature is an important aspect in image processing. [1,2] The significant challenges in appropriate image information retrieval includes diverse aspect of image, database structure, noise existing in an image, availability of images from different perspectives, image quality and human perspective. [3,4,5] Hence, to retrieve correct image

e ISSN: 2584-2854
Volume: 02
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information, some parameters has to be consider like selection of appropriate feature, choice of feature extraction technique, constraint set at the time of feature extraction. As per the requirement of application it may vary upto some extent but the outcome of these mainly focus on the main objectives of feature extraction in image processing are error reduction, obtaining higher accuracy and better visual perception. While using these extracted features, there exist some semantic gap which affect on the quality of the image. For better image quality, semantic gap should be minimum. Image fusion is one of the solution to reduce the semantic gap exist in the image, in which it combines the feature information of two different sources captured of the same object for better perception and image quality.[4,6,7,8]

2. Objective

An image is a vast source of information that precisely represented by features which represents distinguishing characteristics of an image containing behavior of an image in the form of texture, density, color, shape and brightness inside the image. These feature categorizes under the type of pixel level feature, domain specific features, local features and global feature of an image. And hence identification of accurate feature and extraction of appropriate feature is an important aspect in image processing. [1,2] The significant challenges in appropriate image information retrieval includes diverse aspect of image, image database structure, noise existing in an image, availability of images from different perspectives, image quality and human perspective. [3,4,5] Hence, to retrieve correct image information, some parameters has to be consider like selection of appropriate feature, choice of feature extraction technique, constraint set at the time of feature extraction. As per the requirement of application it may vary upto some extent but the outcome of these mainly focus on the main objectives of feature extraction in image processing are error reduction, obtaining higher accuracy and better visual perception. While using these extracted features, there exist some semantic gap which affect on the quality of the image. For better image quality, semantic gap should be minimum. Image fusion is one of the solution to reduce the semantic gap exist in the image, in which it combines the feature information of two different sources captured of the same object for better perception and image quality.[4,6,7,8]

3. Feature Extraction

Feature extraction is a process of retrieving or extracting appropriate feature from image to obtain more accurate information of an image. Face feature extraction is also one of the demanding area in many applications like person identification, sentiment analysis, human computer interaction and image fusion. Eyes, nose and mouth features are the most prominent features in face images. Any informational segment will only be valuable if it effectively and clearly conveys the actual content with clarity and accuracy. There are many factors that may effect on the accuracy of these facial feature detection such as –[9,10,11,12]

- i) Position of The Person from Camera
- ii) Lighting Effect
- iii) Distance from The Camera
- iv) Angle Between Camera and Person
- v) Zoom Setting of the Camera
- vi) Background of The Object Etc.

Due to these factors, there is a chance of semantic gap may present in the image. Semantic gap is the difference or variation between user's high-level understanding of an image and information derived from image's low level feature properties. The existence of the semantic gap is due to the different image capturing conditions including multiresolution aspect, multimodality image, multi-focused image, variations in image capturing time as well as the effect of the background, noise, elimination, distance, angle etc. The minimal semantic gap between images indicates higher image quality and hence the demand of various image processing applications is the minimal semantic gap between images that indicate higher image quality which is used for better interpretation of image.[8,9,13] This discrepancy between information extracted from visual data and the user's understanding of same data in a given circumstance can be decreased through fusion of two or more images.

4. Image Fusion

Image fusion combines significant information from various image sources into a composite image that is more informative and accurate than either of the original input images with minimal data loss or distortion. It produces the fused image without any redundancy or artifacts to make image more robust. The fused process should be suppress irrelevant features that can distract or mislead any subsequent image processing steps. Due to limitations like optical constraints, poor quality image capturing and lack of clarity and quality with a single image sensor, the demand for image fusion for image processing applications has been grown exponentially. The image fusion process must maintains spatial information and improve the visual quality of fused image and must retain all useful and relevant information. [14,15,16]

5. Literature Review

A significant research works are employed by researchers on image fusion to combine information from two or more images to get more precise and exact information about the image. Image fusion in face detection application is complicated due to challenges of face detection. Many researchers are also performed experiments with various modalities to improve face detection accuracy in an unconstrained environment. Several methods are existing for face detection includes Viola and Jones face detection, Convolutional Neural Network (CNN), Edge Orientation Matching and Support Vector Machines (SVM) etc. The most popular and commonly used face detection method is Viola and Jones face detection algorithm that performs better with high accuracy in result upto 93.7 % [17]. The existing image fusion techniques categorized in spatial domain, transform domain and statistical domain. Based on the level of data fusion that occurs, image fusion techniques are classified as pixel-level, feature-level, and decision-level. Depending on the process and data sources, image fusion techniques are classified as, Multiview fusion, Multimodal fusion, Multitemporal fusion, and Multifocus fusion. [18] Spatial domain method directly deals with the pixel value of an image that are manipulated to achieve the required result. Typical spatial-domain fusion method includes principal component analysis (PCA), Intensity Hue Saturation (IHS), averaging method, weighted average method, brovey method, maximum and minimum method etc. This domain uses a series of fusion rules to perform direct selection of appropriate pixels, blocks, or regions from source images in order to compose a fused image without performing any transformation. This approach is simple to execute and takes little time. This method may affects by blurring edges, reduced contrast and reduction of sharpness which has a significant impact on contrast of the image. [19,20,21,22] Shumin et. al. proposed hybrid approach of multi-focus image fusion by focused area decision map and DWT under spatial and transform domain respectively. It produced fused image with lower complexity of algorithm and high quality[20] The discrete cosine transforms (DCT) based image fusion methods are more suitable and time-saving [25] but it also produces blocking artifacts. This problem can be covered by wavelet transform. The spatial domain-based methods can obtain excellent results, but it create undesirable block artifacts and reduced contrast. It also suffers from limitation of fusion rule and often produce unwanted artifacts at the boundaries between focused and non-focused regions. These limitations of spatial domain are well handled by transform domain and it may reduce the artifacts to some extent.[23,24,26] In transform domain (or frequency domain), the pixel value is first transferred into frequency domain by applying fusion methods and further alters its frequency component. [27] In this transform domain, source images are transformed from the space domain to some other domain by using acceptable transforms like wavelets or pyramids. The source images are decomposed into a series of levels or multiscale coefficients depending on transform coefficients. [21,28] Then fuse the corresponding coefficients or sub-images by applying suitable fusion rule on them. Finally fusion decision map (fused image)

e ISSN: 2584-2854
Volume: 02
Issue: 06 June 2024
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obtained by performing inverse transform on it reconstruct the original image. This fused image preserves all of the feature information of source images while reducing spatial distortion. [21, 29] The wavelet-based image fusion technique includes Discrete wavelet transforms (DWT), Stationary wavelet transforms (SWT), Multi-wavelet transforms (MWT) and Complex wavelet transform (CWT). [29] Sanjukta Bhattacharya proposed his work on partial face recognition using image fusion based on transform domain by combination of averaging and DWT method to detect face with uniform lighting and same background of the image to detect eyes from the image. It proved acceptance rate of face recognition between 86.67% and 87.5%. [27] Tanmay Rajpathak also worked on eyes feature detection and given result of successful eye detection with 90% from frontal face images but it failed to detect eyes are closed in the image. [28] Debotosh Bhattacharjee also worked on thermal and visual image fusion for human face recognition in semi-uncontrolled environment with moderate condition of pose, disguise, illumination and occlusions on IRIS database. The image fusion performed using DWT wavalet, PCA and multi-layer perceptron using two fusion rules maximum and weighted avearage for high frequency and low frequency components respectively. It showed improved recognition rate 98.36% and 95.77% on IRIS database and face database respectively [29-31] R. Raghvendra worked for face recognition application using DWT transform domain image fusion. Among the few of these existing research on face features, DWT gives better performance of face feature detection from visible images. But DWT transform domain has limitations of blurry edges and it provides insufficient details. As a solution of these problems of DWT, Stationary Wavelet Transform (SWT) technique has been proposed which is the extension of DWT. [7,20] With all above literature review, we observed that very few research work on multi-temporal face image fusion and hence we considered these this factor for our research work of image fusion [32].

6. Proposed Research Work

In this paper, we focused the image fusion of multi-temporal images to improve the image quality and to reduce semantic gap between images when it captured in different time slot. The research work proposes a multi-temporal image fusion system of eyes facial feature trait based on content-based image retrieval and feature-level image fusion under spatial and transform domain to reduce semantic gap present between two different source images and for better quality image. At the initial stage of the experiment, the primary database is created with the parameters as - time duration of image capture. By considering these parameter, the primary database is created with 70 images of 35 individuals in multi-temporal way under the two different session of one-month gap between two sessions [33]. As discussed above, there are various factors that may affect on the accuracy on the feature detection, so we considered some pre-fixed parameters for our experimental work while capturing these images as-

i) Position of the person - Front position to the camera
ii) Lighting effect - Natural light at day time.
iii) Distance of object from camera and angle between camera and person - 5ft in perpendicular (90 degree angle between camera and person)
iv) Background of the object etc. - Natural background in the room.
v) Facial expressions of all objects are almost try to keep neutral without any special expressions and gestures.

Only one factor that considered with this experimental work is two different time slots while capturing the image [34-37]. Therefore, these images are captured in two different time slots with one month duration gap in two time slots. In this way, we have captured 2 images per person (object) and the analysis performed on total 70 images (35 images * 2 sessions). In second step, the preprocessing is performed on images in which original images are converted into grayscale, removed noise using median filter, contrast adjustment, noise removal using median filter and resized with 10% of the original image size for feature detection and extraction. In this step, the eyes facial features are detected and extracted from these images using Viola Jones feature detection algorithm of source images captured in two different timeslots. We used this algorithm because it produces superior results with greater accuracy from still images when detecting the upper body and because its Haar-like features resemble the facial features of the face in some way by effectively utilizing an integral image to extract eyes feature. These features are characterized into Type 1, Type 2, Type 3 and Type 4. [2,9] To detect eyes feature from the image, Type 1 and Type 2 Haar features are used. Eyes feature detection performed on these 35 individual images using Type 1 and Type 2 Haar feature of Viola Jones algorithm. After feature detection, images are cropped and normalized for feature extraction with size 160*180 as width*height before fused it. These extracted eyes features from two source images then fused under two domains – spatial domain and transform domain to analyze the image quality. PCA algorithm with maximum and average fusion rule from spatial domain and wavelet-based SWT algorithms with level-1 decomposition are used under transform domain to fuse these multi-temporal images. Fig. 1 shows, sample images of image fusion of eyes feature using PCA, SWT and Hybrid Approach of (PCA+SWT). These images are captured in two different time slots with one month duration said as Session I and Session II images. The resultant fused image is comparatively analyzed with two separate algorithms of PCA and SWT with result of hybrid approach (PCA+SWT) and also evaluated with eight quantitative image quality measures such as, Structural Similarity Index Matrix (SSIM), Mean square error (MSE), Normalized Absolute Error (NAE), Correlation Coefficient (CC), Structural Content (SC), Average Difference (AD), Standard Deviation (SD) and Mutual Information (MI). Table 1 shows eyes feature fusion result using PCA, SWT and hybrid approach of PCA+SWT with quality measure. The system implemented in MATLAB and experimental results demonstrate that hybrid approach using both spatial domain and transform domain (PCA+SWT) achieves better result of fused image than other compared algorithms, even though images are captured in two different time-slots from the camera irrespective of background and illumination setting.

The performance of hybrid approach of spatial domain based PCA and transform domain wavelet-based SWT algorithm gives highest feature recognition rate with reduced semantic gap. It is found to be efficient for image fusion of multi-temporal images with reliability, accuracy of feature detection and reduced semantic gap against the appearance variations in lighting and background condition.

7. Result and Discussions

The outcome of this experiment clearly shows that Viola Jones algorithm is successful in extracting eyes feature from these images. Three different image fusion algorithms i.e PCA, SWT and PCA+SWT are applied on these extracted eyes feature to improve the quality of image and get composite image that is more informative and accurate than either of the original input images with reduced semantic gap and minimal data loss or distortion. Figure 1 shows resultant images of image fusion of eyes feature using spatial domain based PCA, transform domain based SWT and hybrid approach of PCA+SWT. Image quality of fused image can be evaluated through either subjective and/or objective approach. Subjective methods are based on the perceptual judgement of a human viewer about the characteristics of an image whereas objective methods are based on computational models that can predict perceptual image quality. These measures are in the form of qualitative or quantitative. The qualitative measures are time consuming, requires careful control of viewing conditions and subject equivalence to render meaningful results whereas, quantitative evaluation methods are beneficial for effective assessments. Table 1 shows resultant values of quantitative image quality measures after image fusion using PCA, SWT and PCA+SWT image fusion algorithm. Table 2 shows summarized result of image quality improvement after image fusion and figure 2 shows graphical representation of image fusion result improvement using PCA, SWT and PCA+SWT with quality measure.

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https://doi.org/10.47392/IRJAEM.2024.0301

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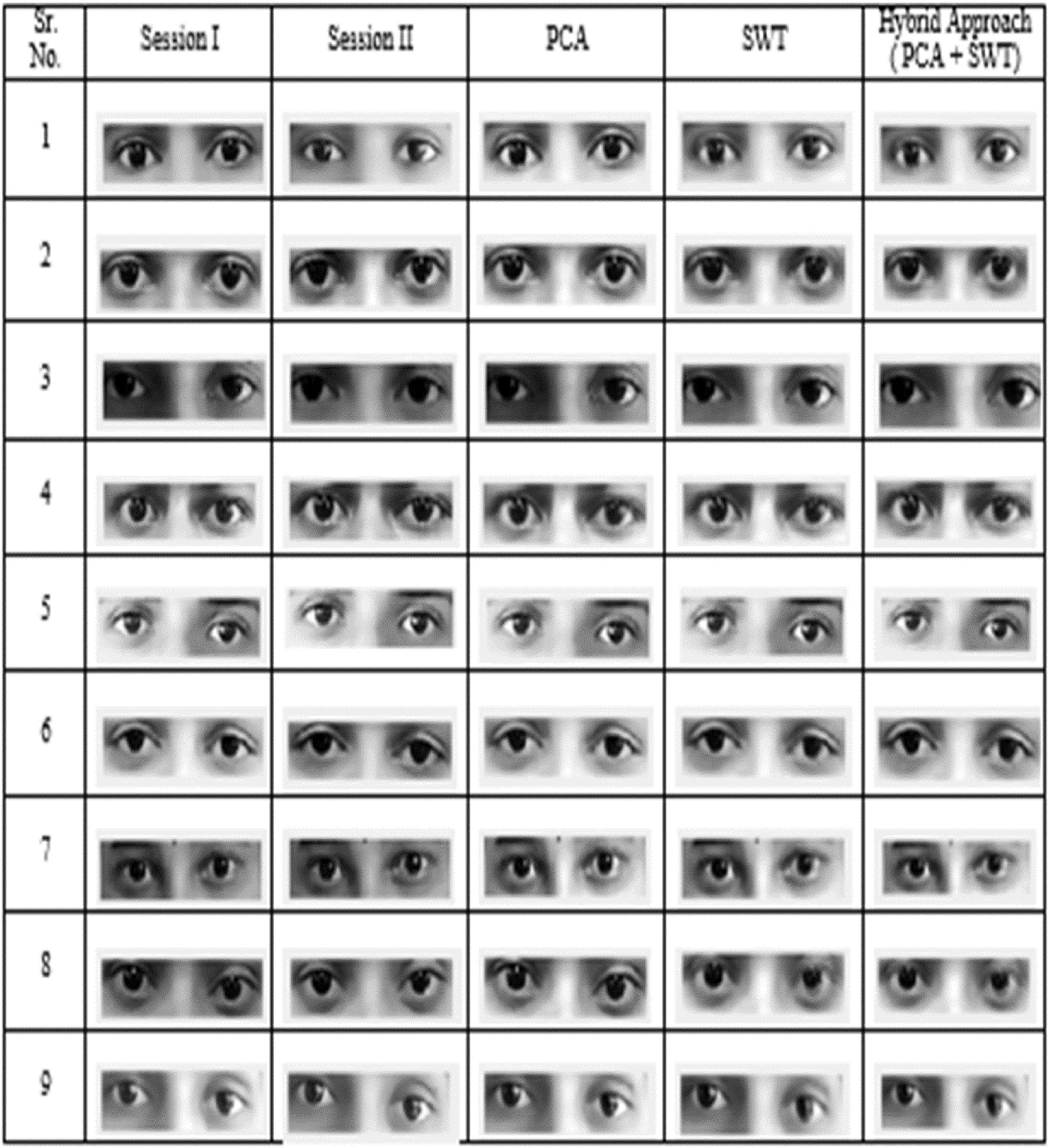

Figure 1 **Sample Images of Image Fusion of Eyes Feature Using PCA, SWT and Hybrid Approach of (PCA+SWT**

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Table 1 Eyes Feature Fusion Using PCA, SWT and Hybrid Approach of PCA+SWT with Quality Measure

Quality Measure		PCA	SWT	PCA + SWT
MSE	MSE1	0.6659	0.6659	0.6659
	MSE2	0.5393	0.1665	0.1668
	MSE3	0.6106	0.1665	0.1664
SSIM	SSIM1	0.4484	0.4484	0.4484
	SSIM2	0.7894	0.7763	0.7827
	SSIM3	0.6002	0.7199	0.7251
NAE	NAE1	0.7398	0.6089	0.6089
	NAE2	0.4575	0.3045	0.3043
	NAE3	0.6089	0.4650	0.4653
CC	CC1	0.2360	0.2360	0.2360
	CC2	0.8130	0.8135	0.8137
	CC3	0.4980	0.7317	0.7311
SC	SC1	0.2239	0.2244	0.7290
	SC2	0.6299	0.6344	0.8040
	SC3	0.7288	0.7288	0.9260
AD	AD1	0.7776	0.3169	0.3168
	AD2	0.1647	0.1592	0.1593
	AD3	0.3168	0.1585	0.1583
SD	SD1	0.5086	0.4359	0.4363
	SD2	0.5134	0.5065	0.5086
	SD3	0.6015	0.6015	0.6015
MI	MI1	0.5900	0.2077	0.1809
	MI2	0.9010	0.7492	0.7281
	MI3	0.9580	0.9583	0.9583

Table 2 Summarized Result of Image Quality Improvement After Image Fusion Using PCA, SWT and Hybrid Approach of PCA +SWT

Quality Measure	PCA	SWT	PCA+SWT
SSIM	0.6002	0.7199	0.7251
MSE	0.6106	0.1665	0.1664
NAE	0.6089	0.4650	0.4653
CC	0.4980	0.7317	0.7311
SC	0.7288	0.7288	0.9260
AD	0.3168	0.1585	0.1583
SD	0.6015	0.6015	0.6015
MI	0.9580	0.9583	0.9583

Figure 2 Image Fusion Result Improvement Using PCA, SWT and PCA+SWT with Quality Measurement

8. Findings

The experimental work is performed on 35 primary photos taken with a smartphone camera in two different sessions with one month duration gap for comparative study of image fusion results using PCA, SWT and PCA+SWT algorithm on multi-temporal images. It has been observed from outcomes of analysis -

1) Mean Squared Error (MSE), Normalized Absolute Error (NAE) and Average Difference (AD) these three quality measures which indicates that how far the fused image from the original image. Here, MSE shows the error between two images and AD gives overall average difference between the corresponding pixels of the two images. Lesser the value of these three parameters shows the better performance of fusion. These values are shown results in the range of 0-1. From this experimental result lesser values of NAE and AD using hybrid approach of PCA+SWT indicates better quality of fused image as compare to the PCA and SWT algorithm seperately.
2) The resultant fused image is also evaluated with five quantitative image measures Structural Similarity Index Matrix (SSIM), Coefficient Correlation (CC), Structural Content (SC), Standard Deviation (SD) and Mutual Information (MI) that shows the structural similarity between source image and fused image. Here, MI estimates the amount of information conveyed from the both source images to the fused image. Higher the values of these five parameters shows the better performance of image fusion. This experimental result shows higher values of these image measures indicates better quality improvement in fused image using hybrid approach of PCA+SWT.

9. Future Scope

The experiments can be analyzed on different types of images such as .gif, .bmp. This experimental work can be extended for face detection using another face feature from more different distances as well as it can be carry out on images with different angles, human pose and facial expressions for exploring more application and accuracy in the system.

Conclusion

The aim of this research are considering different aspects of image fusion for improving spatial resolution, accuracy of images, enhanced capabilities of feature display, reducing semantic gap and visual interpretation of images captured at multi-temporal way. It is concluded that, the result analysis of image fusion clearly shows that hybrid approach of PCA+SWT image fusion techniques reduces the error in fused images and increases the structural and content similarity in multi-temporal images.

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