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Review of Various Multi-Focus Image Fusion Methods

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Abstract - *Image Fusion (IF) is the data fusion method that stored the pictures as the major research elements. It is related to the methods that integrate the multiple image of the similar scene from multi sensor picture data and associate the multiple picture of the similar scene at a diverse number from a single picture sensor. A picture fusion is the method utilised to enhance the visualised interpretation of pictures in diverse applications. It associates the essential features of more than two pictures into a single picture without presenting the artefacts. The traditional picture fusion techniques are mainly effective as injecting the spatial data into the multi spectral images instead of the spatial data in method which are distorted. A lot of research has been done over the past few decades related to the application of the WT (wavelet transform) in IF(image fusion).Consequently, wavelets have achieved a lot is popular because of the power compaction and multi-resolution features. This paper has presented an overview of the multi focus image fusion methods and outcomes from the different wavelet based image fusion methods are compared. In addition, an overview of the image fusion and its sub-types are also explained. In addition the MFIF algorithms have been presented in spatial and frequency domain. It has been surveyed that MFIF may automatically achieve high quality of image.*

Key Words: Image Fusion, Multi focus image fusion, Wavelet transform, Multi-resolution features.

1. INTRODUCTION

Image Fusion is the method of associating the related data from more than two pictures into single picture. Generally, it used diverse pictures of the similar scene from visualised sensor system that are fused to create a single fused picture [1]. It eliminates the related data from input pictures and highlights the useful data and essential features in the fused picture without presenting the unpredictability in the picture [2]. Generally, a single picture may not focus on complete objects in the scene in different conditions, thus multi focus picture fusion method is utilised that fused various pictures of scene captured with focus on different objects with diverse sensors and these pictures are fused to create resulting picture that focused whole objects in the scene. In addition , various levels of the image fusion are described as [3];

1.1 Pixel based Level

It is an easy method of the image fusion that has been considered at the minimum level. In this level, the intensities values of the binary input pictures are combined to provide a unique output picture.

1.2 Feature based Level

It determines the features of the picture if the single picture has partial eye and others consists the misleading feature such as head, nose [4]. At this level, the features of both simple pictures are simply extracted individually, and the fusion algorithm provides improved picture afterwards the feature extraction process.

1.3 Block based level or Region level

It took place on the basis of the pixel-blocks of the picture. It is the highest level method and it contain the multiple stage demonstrations and measurements are computed on the basis of the sections.

Applications of Image Fusion are mainly used for the suitable demonstration of the satellite visualisation in remote sensing or satellite region [5].It is mainly utilised in the medicinal imaging in which the disease are diagnosed by image fusion process by spatial resolution and frequency viewpoints. Moreover, it is used in military surveillance in which all viewpoints utilised to identify the attacks and other perseverance based presentation. For the visualisation of machine, it is mainly used for vision of the image. The fused pictures in robotics predominantly utilised to determine the frequency change in the viewpoints of the pictures. Image fusion is utilised in ANN (Artificial neural network) in three dimensional pictures in which the focal dimension changes in accordance to wavelength conversion [6].

Sections are described as follows; Section I presents a comprehensive overview of the image fusion, different levels and its applications. Section II surveyed various papers and comparative study of different papers, Section III described the brief description of the multi focus image fusion. Section IV elaborated the various algorithms of the multi focus image fusion.

2. LITERATURE SURVEY

Kou, L et al ., 2018[7] proposed research on the technique namely region mosaicking on laplacian pyramid(RMLP) to fuse the multi focus pictures that was captured by the digital microscope. Initially, sum altered laplacian was examined for measuring the focus of the multi focus pictures. After that, the density based growing method was used to segment the focused region mask of very picture. And, then the mask was decomposed into mask pyramid to authenticate the region mosaicking on the laplacian pyramid. The region level pyramid stores the actual data as compared to pixel level. Experimental outcome showed that RMLP have the better performance rate in measuring the quantitative rate as compared to other techniques. Moreover, RMLP was unaffected to noise and may decrease the colour distortion of the fused pictures on binary database. **Liu, S et al., 2019 [8]**implemented a multi focus image fusion(MFIF) method that was appropriate for effective H/W development. This method meaningfully enhanced the velocity by using wavelet and computing the simple fusion rule method. In order to enhance the delay and circuit energy, they restricted the logic operations namely; addition, subtraction and multiplication. Experimental analysis was done on various benchmarks that represented that proposed method may decrease the fusion time interval up to 99.% comparable to state of art opposing techniques without co-operating the quality of fusion. Moreover, the H/W execution of the planned algorithm decreases the circuit region and delay up to 80% and 93% respectively when related with main competitive algorithm in literature, whereas maintaining the same fusion quality. **Zhang, L. et al.,2015[9]**presented an effective image fusion method which related to the merits of the space domain and transform domain. They employed various fusion rules in diverse frequency level in accordance to the various features of low and high frequency domain achieved through the decomposition of the source pictures through wavelet transform. In addition, they engaged the PCA (Principal component analysis) in the lower frequency domain and related to high value selection technique with weight mean technique in higher frequency domain. In the final approach, the output picture was achieved by inverse wavelet transform. Experimental analysis was done that showed that this algorithm may increase the high contrast fusion pictures which were more interesting and contains the useful data as compared to PCA and Wavelet Transform. **Kaur, G. et al., 2016 [10]** reviewed a vast scale different applications like as computer vision, remote sensing, medical imaging, object detection and so forth. Different methods of the multi –focus IF and metrics have the better performance rate that was executed in this research. Different problems have been established that depends on the detailed analysis of the related papers. IF was based on the problem background. Region based technique overwhelm the issue, that presents the better performance rate but the calculation complexity was maximum compared to pixel based techniques. Spatial domain methods have better performance rate comparable to frequency domain because there were shift invariant and retained more detailed data. The improved outcome was achieved by using the image fusion methods that modified image block size. **Pemmaraju, M et al.,2017[11]** presented research on the wavelet based IF method that was employed and developed in the field of the programmable gate array based H/W scheme using Xillinx platform studio EDK 10.1 FPGA Spartan 3E. The FPGA innocations offer essential advanced blocks with adaptable inter-connections to accomplish fast computerised equipment acknowledgement. The FPGA comprises of an arrangement of rationale blocks, for example, flip-flop and some measure of memory. At long last, the proposed algorithm applied to analyses of multi-focus picture combination and correlative picture fusion. The calculation will be moved from PC to FPGA board utilizing JTAG link. The outcome will be moved back to framework to break down equipment asset taken by FPGA utilizing Visual Features. In table I, various papers have been surveyed and the techniques, advantages and issues have been presented.

Table 1: Comparative analysis of the different surveyed papers

Author	year	Technique	Advantage	Issue
Kou, L et al ., [7]	**2018**	RMLP	Shape image through focus	Nosiy filtering
Liu, S et al., [8]	**2019**	DWT	Improved fusion quality	Complexity
Zhang, L. et al., [9]	**2015**	PCA	Low complexity	Blurry images
Kaur, G. et al., [10]	**2016**	DCT	Fusion of medical images	Blurry effects
Pemmaraju, M et al.,[11]	**2017**	FPGA	In remote sensing	Single pipeline

3. CATEGORIES OF THE IMAGE FUSION

Image Fusion is the procedure in which more than two pictures are linked into the single picture retaining the essential characteristics from each of the unique pictures [12]. The main objective of the IF is to combine the supplementary multiple sensor, multiple temporal, and multiple viewpoint data into the single new picture, the quality of which may not be acquired. Normally, picture consist definite type of the data. The major goal of the IF is to enhance the data which is related to specific application. IF is categorised as [13];

3.1 Multiple Exposure IF

Generally, the real time scenes display high dynamic series in colour, luminous and focus. Human brain captured and presents such type of the pictures in an efficient way through

HVS for fusing the pictures, generating a high degree of the practicality. Every picture with the diverse set of the pictures contains the definite region which is highly exposed and focused comparable to similar region in all other pictures [14]. The regions are separated and combined, a visual optimise demonstration of the whole pictures are achieved.

3.2Multiple Temporal IF

The spatial and temporal invention of the tracer determines data that may not be perceived in picture of single time series. Mainly, the dynamic investigation is analysed by representing manual region of interest (ROI) on picture [15]. The picture is selected from various time achievements demonstrating the optimum contrast for required ROI. The average rate of the pixels related to ROI is gathered for every sequence interval and kinetic parameters are included in bio-numerical mode related information through measurement.

3.3 Multiple Focus IF:

It is not probable to achieve the picture which consist whole related objects in focus because of the unrestricted focus dimension of the optical lens. The picture captured from those sensors, consists only objects on complexity of the fields are focused, whereas, other objects are blurred. For achieving the picture with each in focus, multi-focus IF procedure is required to fuse the pictures received from similar viewpoint below various focal settings. Moreover, the fused picture provides an appropriate vision for human and device perception [16].

3.4. Multiple Sensor IF:

The data science investigation related to the growth of the sensor systems focused mainly on method of the extraction of the sensor information about the world. The sense process may be inferred as mapping of formal of the world into group of low dimension [17]. The mapping is numerous that means there are laterally probable configurations of the world that is resulting in the considered sensory information. Therefore in large number of the cases, the unique sensor is appropriate to present and exact perception of the real world.

4. MULTI-FOCUS IMAGE FUSION

Multi Focus image fusion (MFIF) is the procedure of combining more than two pictures of the similar scene into unique complete focus picture [18]. The fused picture is more explanatory that is more appropriate for the visualised perception and processing. Generally, the multi focus image fusion method is computing the focus measurement of the source pictures. In multi focus image fusion, different focus dimensions are utilised. Generally, the pictures are appropriate data for processing job but the restrictions of focusing issue of picture in multi focus pictures are utilised by various researchers [19]. The processing method is developed for suitable vision because single picture may not include maximum data. Hence, it is not easy to focus whole objects in single picture because of the restrictions of the profundity of focus. Generally, the MFIF is the procedure of linking more than two partially defocused pictures into novel picture with all concerned objects that are deeply pictured. Large number of the multi focus image fusion methods is available. These methods are altered, that is based on the input pictures which are fused in area domain or in the conversion domain. The mismatch of the picture features in multi sensor pictures decreases the resemblance among the pictures and it becomes difficult to develop the relation among the pictures. In figure1, is an example of the multi –focus IF during the inspection unnamed aerial vehicle (UAV) [20].

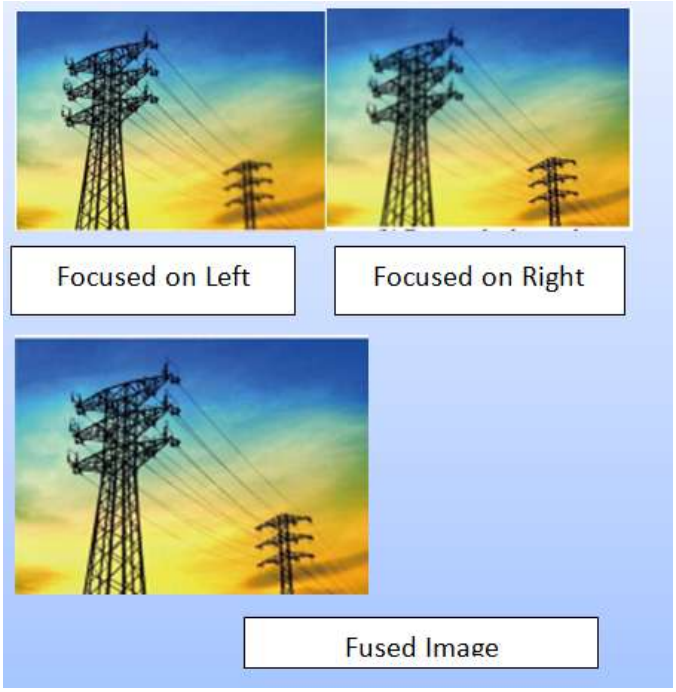

Figure-1 Images of Multi-Focus Image Fusion [18]

5. VARIOUS MULTI-FOCUS IMAGE FUSION ALGORITHMS

Normally, Multi focus image fusion methods are categorised in to different domains as; spatial and frequency domain. Spatial domain IF processes on the direct source pictures of the pixels. The image fusion methods are determined on the unique pixels or blocks of the pixels. Generally, very method performed directly on the pixels, but the source pictures may be categorised in to the blocks [21]. The pixel based IF works on pixel to pixel, while block based IF exhibit on the operations performed to the group of the pixels at definite time. The pixel based method is more appropriate and consist less fault tolerance. In contrast, the block based selection is essential because there is no static block dimension for every picture. Block size influences the fused picture extortionately [22].

In spatial domain, it does not require the transformation, and it is more relevant of the stored faults and less influenced by the noise. Though, the spatial domain caused the fusion spectral distortion and degradation in the fused picture. The domain consist methods like as averaging, maximum /minimum [23]. PCA(principal component analysis , specific colour and standard deviation.

In frequency domain, the source pictures are converted to frequency domain before the image fusion. The resultant picture is achieved by conversion method for the construction of the fused picture when complete operation are evaluated [24]. The standard algorithms of this domain are pyramid based algorithms, DCT (discrete cosine algorithm), and DWT (discrete wavelet algorithm).

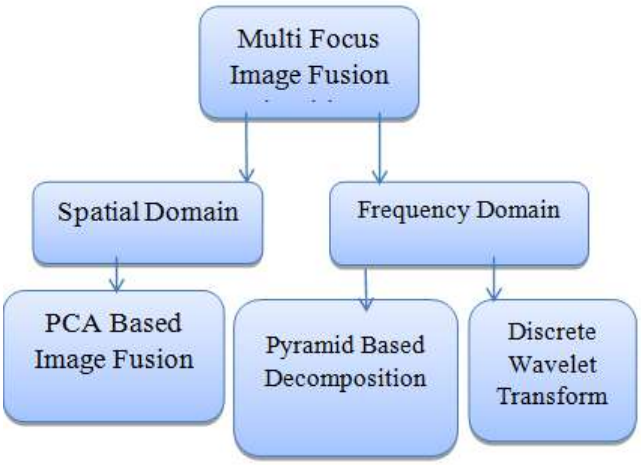

Figure -2 Various Methods of MFIF

5.1 PCA Based Image Fusion

PCA is method containing the mathematical approach of converting the interrelated variable into the unrelated variables that is called as PCA (principal component analysis). The compressed and optimum representation of the dataset is calculated. It is an easy approach that depicts the input demonstration of the data in sensible way but it creates the spectral dreadful conditions. The general applications in PCA are classification and compression of the picture [25]. A mathematical equation is included for the modifications of the factors that is known as the key elements. The initial aspect is achieved through the direction of the optimal variance and other key aspect is the place of sub region at right angle. The other aspect achieved in the optimal variation direction in the sub space at right angle to the binary former. The major benefit is that it avoids definite features from controlling the picture due to large digital values. On other hand, the major issue is that spatial degradation is affected. In fig. 3, the two different images, namely image 1 and image 2 are associated through PCA algorithm, which results to create the fused image.

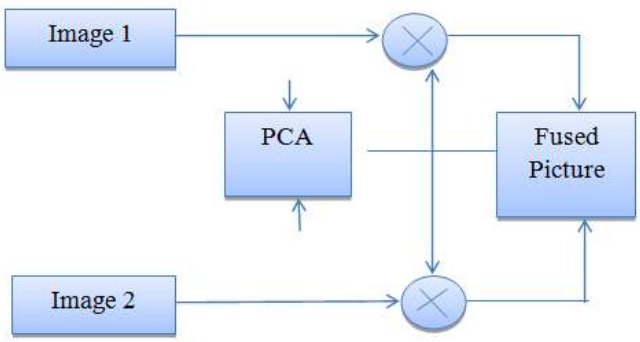

Figure -3 MFIF using PCA

5.2. Pyramid-based IF

It is the fusion technique in the transform domain. Different pyramid based fusion methods are rate of loss pyramid, laplacian and gradient pyramid that is used for various fusion rules of image fusion(IF). In this method, the pyramid rate is achieved from the down sampling of the resource pictures that are fused at pixel level which is based on fusion rules [26]. The fused picture is achieved by rebuilding the fused picture pyramid. The picture pyramid contains the group of the low and band pass duplicates of picture, every duplicate picture demonstrating the pattern data of the varied scale. The major indication is to build the pyramid conversion of the fused picture from pyramid transforms of the source pictures and after that fused pictures is achieved by receiving the inverse pyramid transform. The main goal of this technique is that it presents the data on harsh contrast alteration.

5.3. Discrete Wavelet Transform based IF

Discrete Wavelet Transform (DWT) is the advanced version of the minimum time Fourier transforms. DWT have better performance rate as compared to Fourier transforms and it presents the resolution in required time domain and also frequency domain. In contrast, the Fourier transform provides the better resolution in the frequency domain. The signal is decomposed in to the sine waves at numerous frequency rates in Fourier transform [27]. On other hand, wavelet transform decomposes the signal into scale and shift form of basic wavelet or function. It may not alter the data component available in the signal. Wavelet transform is available on every source pictures to create the fusion decision map that depends on group of the fusion rules. The coefficient map in fused wavelet is built from wavelet coefficient of the resource pictures in accordance to the decision map fusion. The inverse wavelet transform is performed to achieve the fused picture. It presents a suitable signal to noise ratio that is based on the pixel based method. In this method, the final fused picture is achieved with minimum spatial resolution. In fig 4, the two images , image 1 and image 2 are mapped through the coefficients map that are demonstrated through fused coefficient map to form a fused image.

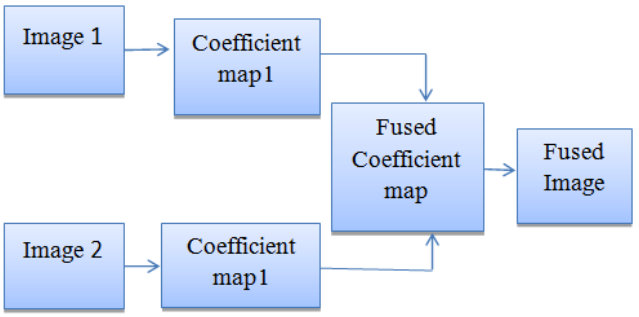

Figure - 4 MFIF using DWT

5.3.1 Stationary Wavelet Transform

DWT is not the time invariant transform; therefore, DWT method is developed to overcome the demerits of the DWT. Hence, the method of the down sampling is suppressed that determines SWT is translation invariant. SWT depends on the notion of no devastation [28]. It applies the DWT and destroys down sampling in the forward and up sampling in the inverse transform. In this method, the iterations are the main stored rows as compared to columns to generate the transform co efficient. The four pictures of the similar size of actual picture are created. Hence, the fused coefficients are fused and inverse discrete SWT are applied to create the fused picture.

5.3.2 Discrete Cosine Transform (DCT)

DCT based IF technique require minimum energy as compared to DWT. Generally, DCT is utilised to describe the sequence of the definite data values in term of the amount of the cosine values at varied frequencies. DCT is main transform utilised in digital image processing(DIP). The pictures are segmented in to different portions as, minimum and higher frequency [29]. RGB pictures are segmented into blocks of 8*8pixels. After that, the pictures are assembled through the metrics of red, green and blue and then converted to the gray scale picture. The two dimensional discrete cosine transform is observed on the gray scale picture. The frequency of the grayscale block is transformed from spatial to frequency domain. If the DCT coefficient is computed, then after applying the fusion rule, the fused DCT co-efficient are achieved. The fused picture is received by getting the inverse DCT.

This technique is more consistent in terms of the time and it is valuable in the real time applications. Large values of the DCT co efficient are focused in the minimum frequency area. However, it contains the appropriate energy density features. When the real information is provided as the input value, the real time outputs are received. In fig .5, the image 1 and image 2 are demonstrated through the fusion rule. Then, the fusion rule is demonstrated from inverse CT to form a fused image.

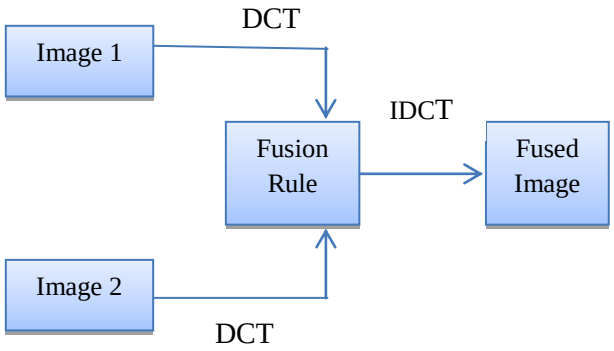

Figure -5 MFIF using DCT

In table II, various algorithms have surveyed in which merits and demerits are presented.

Table 2: Comparison Methods

Fusion agorithms	Domain	Merits	Demerits
PCA	Spatial	It stores the essential elements instead of the complete elements that improved the performance rate	It leads to spectral degradation
DCT	Frequency	It used the cosine elements and it includes the complex operations	Cause the blocking effect.
DWT	Frequency	Decraeases the spectral distortion	Fused images have minimum directional sensitivity

6. CONCLUSION

To conclude, a comparable research on various image fusion methods and related survey of various papers has been presented. The methods of image fusion (IF) used to extract the essential data from source pictures and to improve the visualised quality of the picture was also presented. Lot of research has been done in multi focus image fusion process. Generally, IF is the process in which the source pictures are associated to receive the single focus picture. In addition, the focused picture contains the more appropriate data with complete objects in focus and better understanding of the scene. MFIF is used in diverse applications such as medicinal imaging, remote sensing and so forth. Hence, different MFIF

methods has been described in this paper, though focus measures like as power of gradient of picture, spatial frequency and so forth. Besides, the performance of the MFIF methods is based on the focus region to receive the fused picture. It is examined that the high spatial data is achieved in traditional image fusion methods that lead to issue of the picture blurring. To overwhelm these problems, wavelet based methods are presented. Wavelet presents a high quality of the spectral element with minimum distortion. Hence, in this paper, various wavelet transforms are examined on the pixel based image fusion and the outcomes are compared using various goals based performance measures.

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