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Review of Image Fusion and its Techniques

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Abstract- This paper shows that image fusion is a energetic area in digital image processing. The main goal of image fusion is always to merge information from multiple images of the exact same view in order to deliver only the useful information. It discuss the different image fusion techniques by utilizing these techniques original images were decomposed into low frequency sub band coefficients and band pass direction sub band coefficients based on the non-sub-sampled contour let transform whereas various maps of visual salient features are created by visual salient features the local energy, the contrast as well as the gradient .Low-frequency sub band coefficients are got by utilizing these visual saliency maps. The literature survey is conducted on various recent techniques of image fusion. The survey shows that although present NSCT turns based fusion outperforms over accessible techniques.

Keywords: Image Fusion, Image fusion techniques, Principal Component Analysis (PCA), Non subsampled contour let transform (NSCT), Discrete Wavelet Transform (DWT)

I. INTRODUCTION

Image fusion is usually a vigorous exploration region in digital image processing [1]. It is a mechanism of generating extra informative picture through a set of source picture. The main motive of image fusion is always to assimilate the useful information from major source image in same image or picture.

At present image fusion has grown to be image analysis and computer perspective technology, image fusion are broadly used in computer vision, target recognition, remote sensing, satellite imaging, medial image processing (intensity modulated radiation therapy (IMRT)), military area, etc. [19]. Simultaneously, image fusion continues to be successfully applied to impressive facts for even more image processing, which is best quality online video processing, image detection and image recognition [1].

A. *Level of Image Fusion*

Based on image processing level, image fusion techniques or method is often broken into 3 levels: Low or pixel level fusion, middle or feature level fusion and high or decision level fusion [15].

1) Pixel level fusion: It's really just a low level, easiest as well as popular used approach, associated with area on the pixel which merging the information on the enter image in a single image in relation to the position of the first pixel. Comparison towards other methods like high level and middle level fusion, pixel level fusion provides more accurate result. The low or pixel level fusion methods work either on spatial domain or temporal domain, include method based on averaging method, Brovey method, PCA method, wavelet transform, IHS methods [5].

2) Feature level fusion: It's really just a middle level, which determines and deals with feature of information like point, edge, region, contour and direction obtain by extraction of the features [15]. When this method is needed along with decision levels fusion that provide better fused image, since it has got reduced size and easy to help compress the data. The middle or feature level fusion methods based ones included neural network, region based segmentation and k- means clustering.

3) Decision level fusion: It's really just a top level of the fusion. It extracts the information of the data from low level or middle level fusion to build optimal decision to reach a goal in objective [15]. Before the fusion, data should be obtaining to gain the absolute decision result, so that loss of information can't be ignoring; meantime the cost is very high. High or Decision level fusion methods are broadly used in fuzzy and a supervised FCM, fusion based on support vector machine.

B. *Types of Image Fusion*

1) *Single sensor fusion:* Input image will be taken as a sequence of image by the sensor and then they are fused in an image [3]. Single sensor fusion is fused the set of image even to acquire a new image with information content. It isn't convenient in dark night scene and has some limitation due to capability of sensor.

2) Multi- sensor fusion: Input image will be taken by more than one sensor and then they are fused in an image. It overcomes the issue with single sensor fusion through blend the information through different sensors [3]. It's widely used in military area, medical images and solving the merge information of the different images, remote sensing, infrared and digital camera etc.

3) Multi-focus fusion: Image will be focusing on different image in which some image may be focus on background and other focus on foreground [19]. In 3D view, image is focus with its focal length, original image is divided into region and every region is focusing on at least one channel of the image.

4) Multi-model fusion: In model image fusion obtain the fused image from multiple or different modalities of the

same image. It has commonly used in medical imaging and works on different method of image fusion. These methods are: weighted averaging, fusion in transform domain and object level fusion.

5) Multi- view fusion: In multi view image fusion obtain the fused image from multiple or different view at the same time [2]. These images are taken from different view of the same image.

II. IMAGE FUSION TECHNIQUES

Image fusion techniques are typically segregated within 2 categories-spatial and transform domain fusion. In order to acquire fusion results, several image fusion methods had been approved through various researchers. In this review paper, has been discussed of the different techniques or methods.

A. Spatial Domain

In spatial domain, instantly has value of the pixel of the image as it is, to change desirable result with respect to scene. The methods based on spatial fusion include: Simple Average Method [6], Select Minimum Method [13] and Select Maximum Method, intensity-hue-saturation (HIS) transform, Brovey transform [6], principal component analysis [16].

1) *Simple Average Method:* The simple average method is a pixel based method that repressing the noise of the picture. It can take the pixel through pixel average of the picture. Simple average image fusion is simplest image fusion method, reduces the contrast as a side effect of average [6]. The picture is taken with value of given pixel p(i,j) and then added, summation split by 2.

2) *Brovey Transform (BT):* This transform is color normalization fusion method dedicated to red green blue (RGB). The Brovey transform is a basic procedure in which the value of each low spatial band and high spectral resolution are divided through the amount of the multi spectral band [6]. The Brovey transform is simplest transform for increasing contrast of the picture.

3) *Select Maximum Method:* In select maximum method, has taken maximum value of the each pixel p(i,j) of the picture within the input picture, then compare with one another's in addition to allotted to the related pixel with the outcome picture, then compare to each other's and given to the similar pixel of the output picture. [13].

4) *Select Minimum Method:* In select minimum method, has taken maximum value of the each pixel p(i,j) of the picture within the input picture, then compare with one another's in addition to allotted to the related pixel with the outcome picture, then compare to each other's and given to the similar pixel of the output picture. [12].

5) *Intensity Hue Saturation (IHS) Method:* It can be the most common spatial image fusion method, widely used in commercial application like in remote sensing and based on the red green blue (RGB) transformation. This method is mainly based on three factors: -

- Intensity (I) means brightness of the image.
- Hue (H) means average wavelength of the light.
- Saturation (S) means image purity of the colour.

4) Principal Component Analysis (PCA): It is generally found with image compression, image classification and feature extraction. PCA can be mathematically tooling regarding transform the number of correlated variable into uncorrelated variable [13]. Essential about 3 principal component of the PCA method: 1st principal component will be acquired for being combined some direction having top variance. 2nd principal component needs to situate in sub-space perpendicular to 1st sub-space. 3rd principal component can be obtained in direction of highest variance while subspace perpendicular to the 1st two and so on.

B. Transform Domain

In transform domain, deal directly along with the rate in which value of the pixel is adjusting in spatial domain fusion. Transform domain fusion is firstly transform the input image to its frequency distortion, then performing the processing whatsoever processing it has been to performed and output of the fused image, after performing the inverse transformation.

The various method based on transform domain fusion included multi scale transform (MST), just like pyramid, wavelet, multi scale geometric analysis (MGA) based.

There are classical pyramid based ones like Ratio of low pass pyramid (RP), Laplacian pyramid (LP) and Gradient pyramid (GP). The methods depend upon wavelet transforms likes discrete wavelet transform (DWT) [14], dual tree complex wavelet transform (DTCWT) and stationary wavelet transform (SWT). The methods depend upon multi scale geometric analysis likes Curve-let transform (CVT), ridge-let transform, non-subsampled shear-let transform (NSST), non-subsampled contour-let transform (NSCT) [1].

1) *Pyramid Transform:* The pyramid structure of image was proposed in 1983 by Burt and Adelson to describe image. The actual concept associated with pyramid transform is to decompose the original image into set of several images through certain mathematical operations. Image fusion algorithm dependant on pyramid decomposition transform can be multi-scale methods. It's actually a fusion method while in the transform domain a fusion method generally includes:

a) Laplacian Pyramid (LP): LP makes use of as "Pattern Selective" in order that the composite image is constructed not just a pixel at during the time instead of a feature at a time. Initially, Laplacian pyramid is to set up a pyramid of the source image. Subsequently, the fusion is done at each and every level of decomposition after that lastly it is rebuilt the fused image by undertaking an inverse Laplacian pyramid transform. Laplacian pyramid applied two combinations averaging and selection. Initially, the selection process selects the most salient component pattern within each and every source image and then ripped to its composite pyramid even while a reduced amount of pattern is discarded. Secondly, averaging process is averaged reducing the noise from the source image and averaging is used where the image source is same [3].

b) Ratio of Low Pass Pyramid (RP): RP can associate with human visual system for image fusion. Firstly, input images divided into sets of dark spots as well as light with

the image resolution level. Specific image fusion has performed by choosing spots with maximum absolute luminance of contrast then reconstructed from the pair of spots or patterns are obtained. Thus essential details deals with a relatively high local contrast tend to be maintained within composite image.

c) Gradient pyramid (GP): Gradient Pyramid (GP) of image is received through the use of gradient operators at every level to its Gaussian pyramid. Gradient operators are used in the horizontal, vertical, and a couple diagonal directions. These four directional pyramids combination together for any gradient pyramid. This approach can be used being a gradient pyramid rather than Laplacian with Gradient pyramids utilized rather than Laplacian.

2) *Wavelet Transform:* Wavelets are a mathematical tool that they can be used to create information coming from quite a few different types of data, such as audio signals in addition to images. The subject of wavelet evaluation recently utilized a substantial amount of attention coming from precise researchers in various disciplines. The wavelet transform decomposes the single with only finite energy from the spatial domain within a pair of is the standard from the modular spatial domain connected with orthogonal. Then we analyze the characteristics of the signal from the spatial domain. Compared with traditional analysis, wavelet transform may analyze function from the spatial domain that's improved local capacity connected with the frequency and time. It's the progression in addition to sublimation connected with Fourier transform, which often has plenty of advantages. Wavelet transform can broadly classify into discrete, stationary and multi – resolution based.

a) Discrete Wavelet Transform (DWT): Discrete wavelet transform is a technique to identify local features of the image. The wavelet transform is used to decompose the two dimensional (2-D) image such as 2-D gray scale image in to different number of frequency components called sub bands. Applying wavelet transforms are graphic compression and it transforms the image in to a frequency components. The decomposed sub bands can be used as multi-resolution analysis with assorted resolution levels. In DWT the perception could be enhanced by increasing the decomposition levels [11].The detailed steps to carry out DWT based image fusion technique are as follows:

Step1: Apply discrete wavelet transform (DWT) to each input image separately.

Step2: The input images are decomposed in to four sub band images with various levels of decomposition. The decomposed sub strap graphic is made up of an individual very low frequency and a few high frequency piece of image.

Step3: The decomposed sub band image consists of transform coefficients could be integrated by making use of the specific fusion rule. Step4: Finally performing inverse discrete wavelet transform (IDWT), the fused image could be obtained.

b) Stationary Wavelet Transform (SWT): Stationary Wavelet Transform is often translation –invariant that is similar to DWT but taking out the down sampler and up sampler as on DWT. Several implementing SWT are Pattern recognition, de-noising etc. this transform applied with source image to acquire edge information and fused to quickly attain complete edge information using spatial frequency measurement.

3) *Multi-scale geometrical analysis:* Various tools associated with multi-scale geometrical analysis have already applied to image fusion. Currently, wavelet transforms normally the able to point out one- dimensional. Piece-wise smooth signals, even so in terms of two-dimensional single, would not adeptly protect shape on the identity image. Likewise, separable wavelets are often deficient inside of consuming only limited directional information associated with multi-dimensional signals [1].

a) *Curve-let Transform (CVT):* The Curvelet transform (CVT) is usually a multi-scale transform suggested by Candes and Donoho and is derived from the Ridgelet transform. The Curvelet transform is usually fitted to object which are smooth away from discontinuities over curves. Fourier Transform does not manage point's discontinuities well because discontinuity point is affecting the many Fourier Coefficients in the domain. Additionally, Wavelet transform manages point discontinuities nicely and doesn't handle curve discontinuities well. Curvelet transform manages handle curve discontinuities nicely as is also made to address shape only using limited coefficients. Curvelet transform has got several applications in several areas for example image de-noising, image fusion, image fusion.

b) *Ridge-let Transform:* Ridgelet Transform is just about the category of distinct transforms applying employing basis functions. To facilitate their precise rendering, then will be displayed benefiting from wavelet method throughout the Radon domain. The Radon transform is a power tool involving style and design detection. Therefore Ridgelet transform generally is a tool concerning Ridgelet identification.

c) *Non subsampled Contour-let Transform (NSCT):* To conquer this negatives connected with wavelet when controlling 2-dimension signals, Do and Vetterli shortly before developed a different illustration method titled contourlet, which is actually a illustrational regarding 2-dimension signal. A contourlet transform employs Laplacian pyramid (LP) with regard to multi-scale decomposition, and the directional filter bank (DFB) with regard to directional decomposition. A contourlet transform had been planned to take care of lacking geometric design in the separable two-dimensional wavelet transform. Due to filtering bank, this contourlet remodel isn't only shift-invariant.

Later, throughout 2006, novel multi-scale decomposition strategy, nonsubsampled contourlet transform developing out of contourlet transform, has been recommended by da Cunha. NSCT is not only along with multi-scale, localization, as well as multi-direction, but will also along with qualities regarding shift invariance and the identical measurements in between each sub-band image and the original image. The actual NSCT but not only preserves the characteristics involving contourlet, and also features additional important properties in the shift invariance. The actual contourlet transform and NSCT have the identical approach involving decomposition and reconstruction. [1].

III. RELATED WORK

A brief summary of the related work is given below as follow:

Jianhua Adua et al. (2016) [1] possess proposed to extract and merge the features options that come with the original image, new algorithm based on vision salient features plus cross-contrast. 3 maps with vision salient feature were constructed according to vision salient feature: local energy, particular form a contrast plus gradient respectively in addition to low-frequency sub-band coefficients has been received while using vision saliency maps. Band-pass directional sub-band coefficients was actually got with the cross contrast. Evaluation tests were performed in several image models plus experimental final results illustrate which proposed process executes improved within subjective and objective qualities. Yu Liua et al. (2015) [2] provided a framework through merging MST and SR that can help concurrently get over the particular normal problems with both MST- and SR dependent on image fusion methods . Proposed framework gave specific MST- and also SR-based process was first shown with more aspect on the theoretical perspective, subsequently experimentally verified in addition to multi-focus images, visible-infrared images and healthcare image fusion. Moreover, experimental outcomes illustrate which the proposed fusion design got state-of-the-art method. Yong Jianga et al. (2014) [4] has introduced images fusion can easily make a single image in which identifies the image superior to the individual source image. Fusion system is probably verified with 3 different types of photos and in comparison with 6 single-component fusion methods. In accordance with visible views as well as intent testimonials within the fused benefits, strategy may possibly make improved fused picture inside the experiments, compared to different single-component fusion methods. Gao Guorong et al. (2013) [5] currently have introduced the latest multi-focus photograph fusion criteria good non-subsampled shearlet alter (NSST). This easily outperforms discrete wavelet alter (DWT)-based fusion process, non-subsampled contourlet-transform structured fusion process as well as the NSST-based fusion process with regards to either visible high quality and also goal evaluation. Jianhua Adua et al. (2012) [8] currently have recommended the latest image fusion criteria according to non-subsampled contourlet alter (NSCT) to the fusion regarding multi-focus images. An experimental final results show recommended fusion criteria is capable of significant results in getting the latest image where each of the parts are sharp. Shutao Li et aussi al. (2011) [9] possesses as opposed several multi-resolution decomposition algorithms, exclusively the most up-to-date developed image decomposition strategies, including curvelet and contourlet, to get image fusion. Studies involve the results involving decomposition levels as well as filters in fusion performance. Through evaluating fusion outcome, offer the most effective prospects to get multi-focus images, infrared visual images, as well as healthcare images. A final outcomes present the shift-invariant property to get images fusion. Moreover, deduce which limited filter often provides much better fusion final results compared to long filter, as well as the appropriate establishing to get the various decomposition levels. Minh N. Do and Martin Vetterli et al. (2005) [17] possess pursued a "true" two-dimensional transform which will take a particular implicit geometric composition this crucial around visual information. Specifically, which they developing outcome in a flexible, multi-resolution, local, and also directional image extension making use of contour segments, and is called the particular contourlet transform. Also, create an accurate outcome of a developed filter standard bank and also the associated continuous-domain contourlet expansion by way of a directional multi-resolution research framework. Eventually, display some numerical experiments indicating the potential for contour-lets in many image processing applications. Zhiyun Xue et al. (2004) [19] ought to create a completely new algorithm in order to fuse a color visible image including an affiliated IR photo for such a concealed weapon detection application. The fused image attained by way of the proposed algorithm will keep up with the high resolution of the visible image, combine virtually any concealed weapons detected by way of the IR sensor, plus keep the healthy colouring of the visible image. The proposed fusion was proved by several trial and error results. Tian Guoqiang Ni et al. (2000) [20] have published a new contrast-based process utilizing with wavelet multi resolution analysis. Algorithm criterion can be extremely tightly related to visible attention which is tested through getting started with visible together with IR images. The effect explains which a merged picture might absorb details of the unique image. The particular aesthetic good looks as well as SNRs for the merged picture reveal that up to date practices can have better fusion results than the several former multi resolution fusion methods.

IV. COMPARISON OF DIFFERENT IMAGE FUSION METHODS

S. No.	Author Name/Year	Method	Domain	Advantage	Disadvantage	Measuring Parameters
1	Rohan Ashok Mandhare et al.(2013)	Simple Average [10][11][12]	Spatial	This is actually the most straight forward method of image fusion.	The key disadva-ntage of Pixel levels procedure is the procedure would not provide ensure to have very clear prod-ucts through the pair of graphic.	PSNR- 55.58 EN- 5.23 RMSE- 0.179 SD-32.64

2	Solanki et al.(2011)	Select Maximum [12]	Spatial	Producing highly aimed graphic output result removed from a input graphic when compared to average method.	Pixel level method suffer from blurring impact which usually directly effects on a contrast with the graphic	PSNR-26.86 EN-7.20
3	Rohan Ashok Mandhare et al.(2013)	Brovey Tansform [10]	Spatial	This is a straight forward method for pairing data by diverse sensors. It's a blend of arithmetic procedures and normalizes a spectral band just before these are multiplied together with the panchromatic image.	From vision standpoint averaging process and Brovey process exhibits some color distortions	EN-5.935 SD-17.6 RMSE-0.21 PSNR -46.5
4	V.P.S. Naidu et al.(2008)	PCA[13]	Spatial	PCA is usually a tool which usually alters amount of correlated variable straight into amount of uncorrelated parameters; this property can be utilized within graphic fusion.	Spectral deterioration is found	RMSE-9.86 SNR-51.74 PSNR-76.44 SD-45.23 SSIM-0.95
5	Jianhua Adu et al.(2016)	NSCT[1]	Transform	NSCT gives fast performance as it provides. Multi scale, multi-directional and shift invariant property.	it may result in some halo or gradient reversal artefacts	SD- 41.2832 AG- 3.0435 SF- 6.0831 IE- 4.9546
6	Chetan et al.(2011)	DWT[14]	Transform	This DWT fusion method might out-perform your slandered fusion method with regards to lessening spectral distortion. What's more, it presents greater signal so that you can noises rate as compared to pixel based mostly approach	Around this approach last fused graphic possess a much less spatial resolution.	RMSE-0.179 EN-5.23
7	C.Jothi et al.(2013)	Ridgelet [17]	Transform	This fused graphic might considerably benefit medical examination along with more graphic handling around computer system served diagnosis	Ridgelet fusion results have reduced entropy and greater PSNR.	EN- 6.4938 PSNR -59.86
8	Hannandeep Kaur (2015)	Laplacian Pyramid with DWT [18]	Transform	Pixel plus region-based approaches which is often used with regard to mapping involving in the region and anything about most coefficient band involving supplier images.	It could be enhanced with regard to medical illustrations or photos around medical terminal-ogy for instance CT study, MR, plus X-ray scan .	PSNR - 62.25 MSE -0.064 EN- 7.136 SSI-0.986 MI-1.021 SD-19.860

9	Gonzalo Pajares et al.(2004)	Combination DWT&PCA [11] [16]	Transform	Multistage fusion the place that the graphic is run through fusion twice utilizing productive fusion procedure offer improved upon outcome. Output graphic contained both excessive spatial qualities with high superior spectral content.	This method is definitely intricate around fusion algorithm. Necessary good fusion technique for greater outcome.	PSNR-67.08 EN-7.24
10	Susmitha Vekkot (2009)	Combination of Pixel & Energy Fusion rule [15]	Transform	Protects border information plus line information without having introducing every other disparity towards image.	Complexness involving method increases.	PSNR-27.75

V. GAPS IN LITERATURE WORK

The survey has shown that although existing contour let transforms based fusion outperforms over available techniques but it still suffers from artifacts as it is based on transform domain method. The literature review has demonstrated that the vast majority of established reports have abandoned the followings issues as most of the existing methods are based upon transform domain; therefore, it may result in some halo or gradient reversal artifacts. The after effect of unequal illuminate is also ignored, that might decrease the efficiency of transform based fusion methods. The aftereffect of local variance is also ignored in the majority of existing literature on image fusion techniques. The hybridization of visual salient features, cross contrast with edge weakening guided filter is also ignored for efficient image fusion.

VI. CONCLUSION

Images fusion can easily make a single image in which identifies the scene better than the individual source image. Fusion system is definitely verified on about three var ieties of images and also in comparison with six single-component fusion methods. In this paper the comparison of various image fusion techniques has been discussed by using parameters like PSNR,EN, RMSE, SD. The main objective of vision fusion is to merge information from multiple images of the same view in order to deliver only the useful information. The literature survey is conducted on various recent techniques of image fusion. The survey has shown that although existing contour let transforms based fusion outperforms over available techniques but it still suffers from artifacts as it is based on transform domain method. Therefore in order to reduce the various artifacts further, in near future will propose a new method which will integrate the local variance based edge weakening guided image filter with visual salient features and cross contrast.

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