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Theoretic Study of Image Fusion Techniques – A Survey

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Abstract— Image fusion is the hottest research subtopic of image processing. Fusion is basically extraction of best inputs and conveying to the output. For making an image, which is more suitable for segmentation, extraction of features, object recognition and human visual system, Image fusion is frequently used. It combines complimentary information from different image of the same scene in a single image. Image fusion can be performed at four different process levels which are signal, pixel, feature and decision level according to the stage at which levels fusion takes place. This paper provides survey of some of the various existing techniques applied for image fusion and comparative study of all techniques concludes better approach for its future research. In this paper we also try to find it out what are things that were neglected by the researchers, so our main objective was to find out the gaps in existing literature.

***Keywords*—**BWT, DCT, DWT, DT-CWT, Image fusion , PCA

I. INTRODUCTION

Image fusion is the process that combines information from multiple images of the same scene without producing details that are non-existent in the given images. The resulting image will be more informative than any of the input images. Image fusion is a process of combining information of interest in two or more images of the same scene. The aim of image fusion besides reducing the amount of data in network transmissions is to create new images that are more suitable for the purposes of human and machine perception, and for more image- processing.

Image fusion takes place mainly at four different levels i.e. signal, pixel, feature and decision. In signal-based fusion, signals from different sensors are combined to create a new signal with a better signal-to noise ratio than the original signals. Pixel-based fusion is a low level of fusion and is performed on a pixel-by-pixel basis. It produces a fused image in which information associated with each pixel is determined from a set of pixels in source images to improve the performance of image processing tasks such as segmentation. Feature level is a middle level of fusion requires an extraction of objects recognized in the various data sources. It requires the extraction of important features which are depending on their environment such as pixel intensities, textures, edges etc. These similar features from input images are fused. Decision-level fusion consists of merging information at a higher level of abstraction, combines the results from several algorithms to yield a final fused decision. Input images are processed individually for extraction of information. The information we obtained is then combined applying decision rules to increase further common interpretation.

II. LITERATURE SURVEY

Image fusion is a very important subtopic of image processing. Various image fusion methods have been discussed to reduce the blurring effects, and to enhance the quality features of the image. Related work based on image fusion started basically from mid –eighties. Now we would like to introduce literature survey on image fusion in a chronological order.

Burt (1984) [1] Make use of the laplacian pyramid for efficient computation, he proposed the pyramid algorithms, which was widely used in image fusion

Adleson (1987) [2] proposed a depth of focus imaging proposed method

Lillquist (1988) [3] disclosed an apparatus for composite visible/thermal infrared imaging, same year **Nandhakumar and Aggarwal** [4] working on an approach for computer perception of outdoor scenes. In this approach information was extracted from thermal and visual images, and then valuable information is integrated.

Later **Toet (1989)** [5] introduces a hierarchical image combining technique.The composite images produced by this technique preserve those details from the input images that are most relevant to visual perception. **Rogers et al.** [6] worked on target segmentation in the same year using image fusion of LADAR and passive infrared images, this combination of processed LADAR and forward-looking infrared images can be used for object identification. Simultaneously **Li and Chipman et al.** [7] proposed the discrete wavelet transform (DWT) in image fusion. This paper describes an approach to image fusion using the wavelet transform. When images are combined in wavelet space, we can use different frequency ranges differently.

Koren et al. (1995) [8] presented a steerable dyadic wavelet transform decomposition of multi-sensor images, the maximum local oriented energy is determined at every level of scale and spatial position. **Waxman et al.** [9] generated a real time fused combinations techniques**.** This paper describes how quality of image fusion gets effected .**Li, H et al. (1995)**

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[10] suggested that the wavelet transforms of the input images are appropriately combined, and the new image is obtained by taking the inverse wavelet transform of the wavelet coefficients fused after the rule of maximum selection of local base and a pitch of consistency check is used for feature selection.

O, R et al. (1997) [11] has discussed a novel approach for the fusion of spatially registered images and image sequences. The fusion method includes a shift invariant extension of the DWT, which yields an over complete signal representation. Same year **Y-T, K et al. (1997)** [12] has proposed a bi-histogram equalization for brightness preservation (BBHE) algorithm for contrast enhancement in an images. In this algorithm images is decomposed into two sub images based on the mean of the input image after that histogram equalization is applied to preserve the mean brightness of the given image.

Qing Wang et al. (2004) [13] mainly discuss the structures of image fusion process, which is categorize as hierarchical, overall, and arbitrary fusion structure. Effects of such image fusion structures on the performances of image fusion are analyzed. **He, D et al.** [14] explained that the challenge in image fusion is to fuse two types of images by forming new images integrating both the spectral aspects of the low resolution images and the spatial aspects of the high resolution images.

T.Zaveri, M et al. (2009) [15] proposed a new algorithm. Proposed algorithm is applied on large number of registered images and results are compared using fusion parameters. **Malviya, B et al.** [16] this paper presents pixel based and region based fusion schemes, including a wavelet based approach. An area-based maximum selection rule and the steps of checking consistency are used for feature selection. The performance evaluation was based on various objective metrics and the results are promising, comparable with existing algorithms. **Susmitha Vekkot,P et al**. [17] proposed a new architecture with a hybrid algorithm based pixel selection rules for maximum low frequency approximations fusion mask to filter high frequency detail wavelet decomposition is applied.

Pei, Y et al. (2010) [18] this paper proposes an improved discrete wavelet framework based image fusion algorithm, after studying the principles and features of the discrete wavelet framework. The enhancement is the careful consideration of the high frequency subband image region characteristic. **Haghighat, M et al.** [19] in the same year has explained that discrete cosine transformation (DCT) based methods of image fusion are more suitable and time-saving in real time system. In this paper an effective approach for fusion of multi-focus images based on variance calculated in DCT domain is presented.

Lavanya, A. et al. (2011) [20] proposed a new image fusion method based on wavelet combined IHS and PCA transformations for remotely sensed lunar image data in order to extract features accurately. Same year **Ghimire, D et al.** [21] proposed a method to enhance the color images based on nonlinear transfer function and pixel neighborhood by preserving details.**Haozheng Ren et al.** [22] in the same year has explained that the image fusion is one of the important embranchments of data fusion. Its motive is to synthesis multi-image information in one scene to one image which is more suitable to human vision and computer vision or more adapt to further image processing, such as target identification. **Xing,S et al**.[23] has presented an image fusion method based on NSCT and robustness analysis that focus on the fusion of infrared and visible images for better contrast, clarity and night vision. **Mohamed, M et al.** [24] addresses various issues in image fusion: Fused two images by different techniques which present in this research, Quality assessment ,Comparison of different techniques to determine the best approach and Implement the best technique by using Field Programmable Gate Arrays (FPGA).**Patil, U et al.** [25] has focused on image fusion algorithm using hierarchical PCA. Hierarchical multiscale and multiresolution image processing techniques, pyramid decomposition are the base for the majority of image fusion algorithms. **A.SomaSekhar et al.** [26] has proposed a Novel multi-resolution fusion algorithm for medical diagnosis using integrated PCA and wavelet transforms .A multi-resolution based fusion is obtained by combining the aspects of region and pixel-based fusion. **M.Chandana, S.et al.** [27] has proposed the image fusion technique includes following steps: first, DWT is applied to obtain the wavelet coefficients of the source images. The coefficients are processed with different fusion rules to get the primary fused image, on which the fusion rule is again applied to get the secondary fused image. Both primary and secondary images are processed again with most efficient fusion rule to get the final fused image.**Chetan K. Solanki , P et al. [28]** in the same year has proposed the spatial technique resulting in highly focused image output obtained from the input image as compared to the average methods . But since it is a spatial domain technique which is based on pixel so blurring occurs which directly affects the image contrast.

Kiran , P et al. (2012)[29] proposed the Fast Discrete Curvelet Transform technique using Wrapper algorithm based image fusion has been implemented, tested and compared with Wavelet-based fusion technique. Curvelet Based Image fusion is the most suitable for medical imaging. **Aribi, W et al.** [30]in the same year explained that the quality of the medical image can be evaluated by several subjective techniques. However, the objective technical analysis of the quality of medical imaging has been recently proposed. The merging of information from different imaging modalities allows a more accurate analysis.

Sruthy, S et al. (2013) [31] this paper focuses on the development of an image fusion method using Dual Tree Complex Wavelet Transform. The results show the suggested algorithm has a better visual quality than the base methods. Also the standard of the fused image has been evaluated using a set of quality metrics. **Desale, R.P et al.** [32] This paper explains the, Process Flow Diagrams, formulation and algorithms of PCA (principal Component Analysis), DCT (Discrete Cosine Transform) and DWT based image fusion techniques. In this paper, two algorithms based on DWT are proposed, these algorithms are pixel averaging & maximum pixel replacement approach.

Anita, S.John Nisha et al. [33] has shown that the most of the existing fusion techniques such as Principal Component Analysis (PCA), Intensity-Hue-Saturation (IHS), Wavelet Transform (WT) yields color distortion in other words it is also known as spectral distortion problem. The above said fusion techniques require additional transformation to increase spatial information and also decrease spectral distortion in fused image. **Om, p et al.2013** [34] has proposed a Biorthogonal wavelet transform (BWT) based image fusion method using absolute maximum fusion rule. **Y. Asnathet al.** [35] proposed a fusion method in this, the image blocks with higher value of AC coefficients is absorbed into the fused image. It is extremely fast as it does not involve any complex floating point arithmetic operations .The proposed fusion technique considerably reduces the computational complexity without compromising image quality and for energy consumption analysis.

Image fusion can enhance a digital image without spoiling it. The enhancement methods are of two types namely spatial domain methods and frequency domain methods. In spatial domain techniques, we mainly deal with the pixel value of an image; pixel values are manipulated to achieve the desired result. In frequency domain methods the pixel values is first transferred into domain methods by applying dct and dft based fusion methods and further image is enhanced by changing frequency component of an image . Image fusion techniques can be applied to any field. Some of the main applications of image fusion lie in the field of robotics, remote sensing, geometric correction of the image, enhancing certain features not visible in either of the single data alone, concealed weapon detection, remote sensing , medical diagnosis, defect inspection military surveillance , navigation , satellite imaging , rob vision.

III. OBJECTIVE OF IMAGE FUSION ALGORITHMS

In general the objective of image fusion algorithms are desired to achieve

- Extract all the meaningful information from the source images.
- They should not introduce any artifacts or inconsistencies which will distract human observers or the following processing.
- They should be Reliable and robust to imperfections such as mis-registration
- Image fusion algorithm should be capable of faster acquisition of information
- Image fusion algorithm should be capable of cost effective acquisition of information.

TABLE I : COMPRATIVE EVALUATION

S.NO.	TECHNIQUES	FEATURES
1	Pyramid algorithm [1]	1. Effective technique 2. It provides a neural like image representation which is robust, compact and appropriate for a variety of higher level tasks 3. Shows similarity with the human visual system
2	Depth of focus imaging proposed method[2]	1. The Laplacian technique was used 2. Concept of different focal length is used to get better image
3	Integrated analysis approach[4]	1. The integration of information 2. Features are based on surface heat flux.
4	Hierarchical image combining technique[5]	1. Preservation of details suitable for visual perception. 2. Fused image which we get present a more detailed representation of the scene. 3. Mainly used for transfer of information from one image to another.
5	Multisensor fusion of LADAR and passive infrared imagery[6]	1. This technique allows segmentation of images of real scenes containing objects in the presence of clutter.
6	Discrete wavelet transform (DWT)[33] [28]	1. Wavelet transform is used. 2. When images are merged in wavelet space, we can process different frequency ranges. 3. It can be used in various application like cloud removal where the analyst could look at a single image and see all important details in his area of interest
7	Steerable Dyadic Wavelet Transform[8]	1. It is based on multiscale analysis along arbitrary orientations 2. The transform was shift-in-variant and there allowed no aliasing in the filter implementation, both properties are highly desirable for image fusion applications
8	A real time fused combinations techniques. [9]	1. Quality of fused image is affected by multiple dimensions, including illumination of scene, reflectance contrast, thermal contrast, sensor resolution, noise-limited resolution, adaptive local gain & contrast enhancement, cleaning of noise, and fusion methodology.
9	Multi-sensor image fusion using the wavelet transform[6][7]	1. The wavelet transforms of the input images are accordingly combined, and the new image is obtained by taking the inverse wavelet transform of the fused wavelet coefficients. 2. Area based on maximum selection rule 3. Consistency verification step are used for feature selection.
10	Shift-Invariant Wavelet Transform[11]	1. The advantage of the method is the improved temporal stability and consistency of the fused sequence compared

		to other existing fusion methods 2. This method outperforms the standard wavelet fusion scheme in both the fusion of still images and image sequences.
11	Bi-Histogram Equalization Method. [12]	1. Method for contrast enhancement. 2. The proposed algorithm preserves the mean brightness of a given image extremely well compared to typical histogram equalization while enhancing the contrast 3. Many applications can be made possible by utilizing the BBHE algorithm in the area of consumer electronics.
12	Fusion Structures on Image Fusion(hierarchal fusion process) [14][13]	1. In this techniques hyperspectral image data is fused using the same wavelet transform. but applying different fusion structure 2. Performances are not only related to fusion techniques but also to fusion structures.
13	A new technique for multiresolution image fusion[14]	1. It increases the spatial information and decrease the spectral distortion in fused image.
14	Combination of Pixel and Energy Fusion rules [17]	1. It preserves boundary information and structural details. 2. No consistencies. 3. Complex method
15	Region Based Multi-focus Image Fusion Method. [15]	1. The algorithm performs better than pixel based fusion method. 2. Simulation results of Region Based multifocus Method preserves more information compared to reported pixel based method. 3. It is less responsive to noise, misregistration and hardly any blurring effect or change of contrast seen.
16	Simple Average[16] [27]	1. This is the simplest method of image fusion. 2. The main disadvantage of Pixel level method is that this method does not give guarantee to have a clear objects from the set of images.
17	Simple Maximum [16] [28]	1. Resulting in highly focused image output obtained from the input image as compared to average method 2. Pixel level method are affected by blurring effect which directly affect on the contrast of the image
18	An Improved Wavelet Transformed Based Image Fusion Algorithm [18]	1. This method studies the quality assessment of the image fusion 2. The performance of this algorithm has been evaluated on the following matrices: Subjective and Objective assessment: 3. The assessment results shows that an improved wavelet transform based image fusion algorithm produces better results for image fusion
19	Discrete Cosine Transform based Image Fusion Techniques[19]	1. It is observed that Fusion performance is not good while using the algorithms with block size less than 8x8 and also the block size equivalent to the image size itself.
20	A new image fusion algorithm using hierarchical PCA[25]	1. Feature extraction. 2. It provides better result for fusion of multimodal images and is more informative than individual pyramid. 3. The aim is to generate the composite Image, which provides more information than its input images.
21	Color Image enhancement by using Non linear Transfer Function.[21]	1. Feature extraction. 2. It provides better result for fusion of multimodal images and is more informative than individual pyramid. 3. The goal is to generate the composite Image, which is more informative than its input images.
22	FPGA based fusion method[24]	1. FPGA is a hardware based design approach. 2. It is able to perform a parallel operation that is we can read, write and process the data simultaneously. 3. It provides flexibility to reprogram and upgrade new standards and values.
23	Ratio and Contrast Techniques. [30]	1. Comparison of various pyramid algorithms like FSD, Gradient, DWT, ratio to show ratio outperforms under various image fusion algorithms. 2. Techniques are most suitable for the analysis.
24	Comparative Analysis of PCA, DCT & DWT based Image Fusion Techniques[32]	1. DWT based techniques are more favourable as they provide better results for image fusion. 2. Two methods are used pixel averaging and maximum pixel replacement 3. The fused image is made by combining magnified information from the input images.

25	DT-CWT based Image Fusion[29]	1. The technique works on improving the visual quality of images. 2. DT-CWT is a reconstruction process using inverse dual tree complex wavelet transform. 3. Best approach for visual assessment and gives best results for images.

IV. DISCUSSION AND CONCLUSION

After conducting the literature survey we finally found that image fusion may introduces some artifacts on output image, In that case before implementing fusion techniques, we should also think about the filtering and image restoration approaches, we come to the following conclusion:

- Till now researchers has not worked on the types of filter which can properly eliminate the noise from the fused image.
- Till now restoration technique is not applied on image fusion algorithm.
- Since most existing methods are based on the transformation, therefore, it is possible that the results of some color artifacts that can degrade performance of the transform based vision fusion methods.
- We also found that the problem of uneven illumination (varying light conditions) has also been neglected in most existing work on the fusion.
- Images which possess complex background may not be fused correctly, as it very difficult to extract the useful objects or regions.

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