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A Study on Multi-Focus Image Fusion Based on NSCT and Focused Area Detection

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Abstract— *In this paper, a study on multi-focus image fusion methods having the ability to conquer the problems in transform domain method and to avoid the disabilities occurring in spatial domain method has been introduced. To gain an image with high quality and with all spectral and spatial information, it is important to recover the images from various multi-sensor images. Image fusions are mainly classified as transform domain image fusion and spatial domain image fusion. The main aim in multi-focus image fusion is to overcome the limitation in camera depth. The first step is to decompose the images using NSCT thus dividing the images into low and high frequency components. Then applying certain fusion rules with respect to the low frequency and high frequency an initial fusion image is obtained. By comparing the similarities between the initial fused images and source images a decision map is obtained by certain mathematical morphological procedures. The final image fusion is based on the decision map by selecting the pixels from the focused areas and obtaining the pixels at the boundaries as their respective pixels in the initial fused image.*

Keywords— *Depth of field, fusion rules, human visual system, image fusion, mathematical morphology, spectral information.*

I. INTRODUCTION

In the emerging fields of digital imaging and certain other areas like remote sensing, computer vision, biomedical imaging etc., the need of image fusion is been increasing in a rapid manner. Image fusion is a technique to combine two or more images of a same scenario with the entire objects in focus [1]. Thus, by combining the images of same scenario with all the areas in focus a new image with more accuracy and absolute image that is appropriate for a human operator can be generated.

By demanding more wide-ranging solutions to a large number of applications multi-focus image fusion technique is a very good method [2]. For several situations in image processing it is necessary to achieve an image with high spectral and high spatial information in a single image. The information with all details cannot be achieved in a single picture when the instruments are used. The instruments are not capable of providing high spectral and spatial information either by designs or because of observational constraints. Image fusion is one of the most relevant solutions in such situations [3].

Image fusion was introduced to combine objects of a same scenario from several sensors and this is mainly because of the limited depth in focusing of digital cameras. Due to the limited optical lens focusing several objects were not in focus, i.e., some objects at a particular area will be blurred [4]. But people need an image with all the objects in focus. Thus, to overcome this situation image fusion was introduced by containing all the objects in focus.

Image fusion methods are generally divided into spatial domain technique and transform domain technique. In spatial domain technique the image fusion is done by applying the techniques directly on pixel gray level of the input images. And thus it is also known as single scale fusion method. Some of the main spatial domain approaches are Brovery method, Principal Component Analysis (PCA), high pass filtering based techniques. In transform domain techniques, each input images undergoes mathematical procedures and is decomposed into a series of images. Then the fused image is obtained by applying the inverse mathematical transform. So the transform domain technique is also known as multi scale fusion method.

In spatial domain technique the simplest method is to take the average of the source images pixel by pixel. Even though it is a very simple method many disadvantages take place, such as, reduction in contrast, reduced quality of the images etc. To avoid these side effects many researchers proposed a method by dividing them into homogeneous sized blocks and replacing them with a single pixel. Evaluating the blocks is clear or not is done by combining the blocks in terms of clarity index. They may advance the convergence between each pixel but produces block effects that reduce the quality of fused image. Block effects [5] causes mainly because it is difficult to determine the size of sub-blocks. If the block size is larger it is easy to determine the clear and blurred areas and if it is small sized block selection error occurs in the sub blocks. Focused region based method is another spatial domain technique that is able to identify the clear regions of the source images and then copying the pixels directly to the fused image. But they generate abnormal information and discontinuities at the boundaries. So it is difficult to determine the boundaries accurately. These side effects results in reduced visual quality of the fused image.

Transform domain technique are the most commonly used image fusion techniques and some of the important methods are the Laplacian Pyramid Transform, Gradient Pyramid Transform, Wavelet Transform, Log-Gabor transforms etc.

II. RELATED WORKS

To take care of the issues formed during the transform domain method and spatial domain method, V. Aslantas et al.

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[6] and I. De et al. [5] have individually proposed the differential evolution calculation and the quad-tree structure strategy to take care of the issue of how to decide the measure of sub-pieces. The artificial neural network (ANN) strategy and bilateral gradient technique have been proposed individually by S. Li et al. [7] and J. Tian et al. [8] to enhance the exactness of the sub-block determination. The fusion execution of these techniques is enhanced with newer traditional block based strategies. Be that as it may, "block effect" can't be dispensed with totally in these strategies, particularly when a similar sub-block has both an unmistakable area and an obscured region. Another imperative spatial-based technique called the focus region based strategy can identify the unmistakable districts of source images, and after that straight forwardly copy the pixels from clear areas into the fused images [9]. In any case, these strategies may produce artificial data and irregular phenomena at the limits of boundary areas on the grounds that the limit can't be resolved precisely. These impacts will diminish the visual loyalty of the fused image.

Recently, the more well known combination techniques utilizing Multi-scale Transform (MST) have been researched in a many ways, including the Laplacian Pyramid Transform [10], Gradient Pyramid Transform (GP) [11], Wavelet Transform [12], Log-Gabor Transform and other MST [13]. There is confirmation that MST with flag deterioration is like the human visual system (HVS). Contrasted and spatial-based strategies, the techniques utilizing MST effectively defeat the detriments that have been specified previously. The purpose behind this is the decay coefficients of MST consider the detail of the source images and chooses them out to create combined picture. As we probably am aware, the wavelet analysis, with its upstanding confined eccentricity in both the time and frequency spaces, has turned out to be a standout amongst the most regularly utilized as a part of the field of MST utilized for picture combination.

With the developing of hypothetical reviews, techniques have been proposed for image fusion that is superior to anything wavelet transforms, for example, wavelet packet transform and wavelet frame transform. Be that as it may, wavelet analysis can't effectively speak to the line singularities and plane singularities of the pictures. Combined with the impediments toward the 2D separable wavelets, wavelet analysis consequently can't speak to the bearings of the edges of pictures precisely [14].

To conquer these weaknesses of the wavelet transform, M. N. Do and M. Vetterli [13] proposed the Contourlet Transform (CT), which can give the asymptotic ideal representation of shapes and has been effectively utilized for image fusion. Nonetheless, the here and there inspecting procedure of Contourlet deterioration and reproduction brings about the CT lacking movement invariance and having pseudo-Gibbs marvels in the fused image. On the establishment of CT, A. L. Cunha et al. [15] proposed the Non sub sampled Contourlet Transform (NSCT). NSCT acquires the upsides of CT, while likewise having shift-invariance and successfully smothering Pseudo-Gibbs marvels. In this way, the NSCT is more reasonable for image fusion.

The MST-based image fusion strategy can essentially upgrade the visual impact, yet in the concentration region of the source image, clarity of the image sources will have difference degrees of misfortune. That is on the grounds that, during the time spent Multi-scale decomposition and reproduction, uncalled for choice of combination guidelines regularly causes the loss of valuable data in the source picture. This imperfection in the MST-based picture combination strategy is practically difficult to totally maintain a strategic distance from [2].

It is imperative that the greater part of the picture combination techniques depend on the suspicion that the source pictures are noise free, and they can deliver amazing melded pictures in the theory. Nonetheless, basically, the pictures are frequently tainted by common noise the procedures of picture acquisition. In 2010, B. Yang and S. Li [16] proposed another multi-focus image fusion calculation utilizing the sparse representation. The technique performs exceptionally well with both perfect and noisy pictures. However, this plan is confounded and time consuming.

In view of the above investigation, a image fusion technique in light of NSCT and focused area detection is proposed in this paper. This technique, which combines the benefits of both the transform based and spatial-based strategies, not just conquers the deformities of MST-based techniques, additionally disposes of "block effect".

III. FUNDAMENTALS

The proposed method is based on the concepts related to NSCT and image fusion descriptors. NSCT means Non sub-sampled Contourlet Transform.

A. Non Sub-Sampled Contourlet Transform

CT could be isolated under two stages, including those Laplacian Pyramid (LP) and Directional Filter bank (DFB) that offers an effective directional multi-resolution picture representational. Around them, LP is primary used to catch those side of the point singularities, followed by DFB will connect those solitary perspective under straight structures. LP is utilized to break down the first pictures. Under low recurrence and high back sub-images. The DFB isolates the high frequency sub-bands to directional sub-bands. Throughout the acknowledgment of the CT, the decomposition also develops filters of LP that need aid distinct bi-orthogonal filters for data transfer capacity more stupendous over π/2.

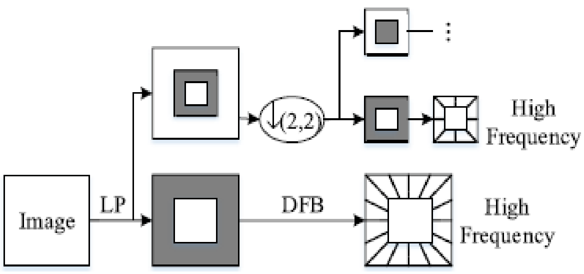

Fig. 1. Contourlet decomposed schematic diagram.

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As stated by the sampling theorem, the pseudo-Gibbs phenomena might show up clinched alongside low and high frequency sub-images for LP space Directional sub-bands which hail starting with those high back sub-images. DFB shifting might likewise show up those pseudo-Gibbs phenomena. These phenomena might debilitate the directional selectivity of the CT to some degree. Figure 1 shows the schematic representation of Contourlet Decomposition.

To tackle this problem, A. L. Cunha proposed NSCT dependent upon those hypothesis of CT. NSCT inherits the point for CT, enhances directional selectivity, shift-invariance, viably defeats those pseudo-Gibbs phenomena. NSCT may be in view of Non subsampled Pyramid filter banks (NSPFB) also Non-subsampled Directional Filter Banks (NSDFB). Figure 2 provides for the non-subsampled contourlet decomposition skeleton with k = 2 levels.

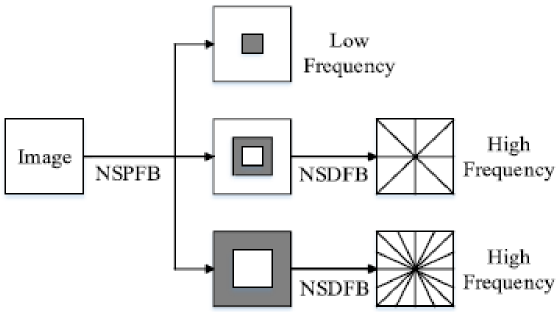

Fig. 2. Non Sub-sampled contourlet decomposed schematic diagram.

The NSPFB ensures the multi-scale execution by making utilization of any two channel Non sub-sampled filter bank, and low frequency sub-image, furthermore particular case high frequency sub-image that might be generated toward every decay level. The ensuing decomposition levels for Non sub-sampled Pyramid (NSP) are carried out to break down those low recurrence part available for readily iteration that should catch those offering or plane singularities in the picture. Similarly as a result, NSP could acquire k +1 sub-images, including the one low frequency k high back sub-images. These sub-images need the same extent similarly as those hotspot pictures. Those NSDFB may be two channel Non-sub-sampled channel banks constructed toward eliminating those down-samplers and up-samplers joining those Directional filter banks in the DFB. NSDFB permits those course decomposition for l levels to each high frequency sub-images starting with NSPFB, produces 2^l directional sub-images for those same measure, similarly as the wellspring pictures. Thus, those NSDFB gives the NSCT the multi-direction performance the more exact directional point of interest data to get all the more exact comes about. Therefore, NSCT prompts. superior recurrence selectivity and need a critical property of the shift-invariance because of non-subsampled operation. The size about separate sub-images deteriorated eventually. Hence, NSCT performs better selection of frequencies and has all the properties of CT.

B. *NSCT- Based Image Fusion*

Here, the NSCT based image fusion scheme is described briefly. Now, by considering a pair of input images A and B, the NSCT image fusion can be explained using the following steps:

Step 1: By analysing the input images A and B using NSCT, one low frequency image and a series of high frequency images can be obtained.

Step 2: Using certain fusion rules low frequency sub-bands and high frequency sub-bands can be obtained.

Step 3: Inverse NSCT is done after the second step and initial fused image is obtained.

The image fusion diagram based on NSCT is shown in the figure 3.

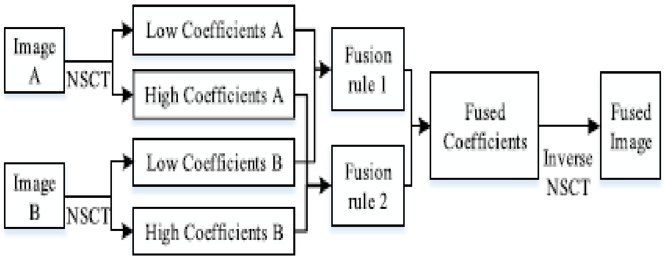

Fig. 3. Schematic diagram of NSCT- based fusion algorithm.

IV. Initial Fused Image Based on NSCT

This segment gives the low and high frequency fusion rules in the NSCT domain for the initial fused image. With the useful properties of NSCT for image fusion, NSCT decomposition and reproduction to acquire the initial fused image is chosen. For an MST- based image fusion it is easy to do the image fusion practically with NSCT algorithm using the fusion rules, which will influence the execution of the fusion algorithm. So as to attain better performance, SML built local visual contrast and local Log-Gabor energy are introduced and used to combine the high and low frequency coefficients respectively[17].

A. *Fusion of Low Frequency Sub-bands*

The coefficients in the low frequency sub-bands speaking to those estimated majority of the data from claiming the components of source images, reflect the gray part from source images also hold those with the greater energy about the source images. To spatial-based multi-focus image fusion a significant number average centre measurements, for example, energy of image gradient, Spatial Frequency, Tenengrad, laplacian energy and also SML can also be compared. SML turns out itself making the best measurement. In the transform domain area SML will be additionally more effective and can produce the best fused image results.

As stated by psychological and physiological research, HVS may be very delicate to the local image contrast keeping instead of the pixel value itself. This requirement helps the proposed version of local visual contrast to recognize and also make reasonable estimation of SML. Those combination standards for low frequency coefficients exhibited in this article utilizes SML built local visual contrast by keeping the recommended definition for SML built local built contrast [18]. Not only by keeping the proposed definitions , they just recognizes the non-linear relationship of those contrast

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affectability edge about HVS and the foundation luminance as well as takes the place of a single pixel with measuring the nearby contrast of the low frequency sub-band. Therefore SML based local visual contrast keeping extracts that's should have a chance to be exchanged starting with low frequency coefficients to fused coefficients.

B. *Fusion of High Frequency Sub Bands*

The high frequency coefficient sub-bands represents the thorough segments of the source images taking into considerations such as edges, textures, boundaries, etc. Normally, the coefficients for larger absolute values are viewed as the coefficients with more obvious point by point characteristics or sharp brilliance changes, and it is to be noted that the high frequency components include the noise that may reduce the fusion performance and cause miscalculations. Choosing coefficients with larger absolute values for the fusion performance in high frequency components can be taken into account. But due to the causing of miscalculation of the sharpness value it can be proved that noise is present. Thus, by comparing various methods and to overcome the difficulties mentioned and combining the basics of local energy, a novel fusion rule is proposed on Log-Gabor energy for high frequency components. Using the Log Gabor energy it is found that the images can be in both noisy and clear images. The visual effect to see an image with human eye cannot detect all the imperfections. So, it was found that the Log-Gabor filters could improve the performance of overall fusion process [19].

To obtain a keen absolute feature extraction, with the help of Gabor filters Log-Gabor filters is designed. When compared with several other transfer functions it is found that Log-Gabor filters are more suitable than any other fusion rules. Thus Log-Gabor filters obtain high spatial orientation and high spectrum information and reflect the frequency response and improve the accuracy of the source images. Hence, it was proven for high frequency sub bands that the Log- Gabor filters is well suited than any other techniques.

V. Focused Area Detection and the Proposed Image Fusion Method

The proposed method of multi-focus image fusion is designed along with some motivation factors. To approach the proposed framework a fusion algorithm is described along with NSCT and has the following descriptions:

A. *Focused Area Detection*

In the process from claiming MST, for example, such that NSCT, decomposition and remaking will inescapably lose suitable data that is held in the focused area about source images. Thus those source images, following NSCT-based initial fusion are transformed to expand focused area detection [20]. The following steps that detects the focused area of the image fusion will be guiding the useful information about the fused image which gives a image that contains all the information and accurate fusion results without lossless data. The proposed schematic method of image fusion algorithm is shown in the figure 4.

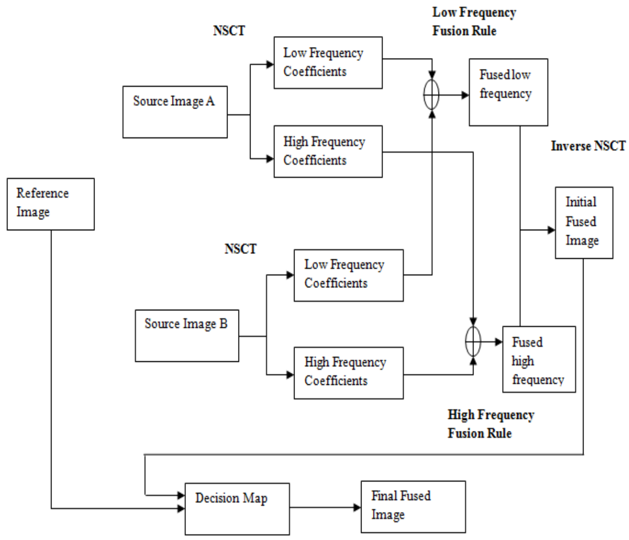

Fig. 4. Proposed framework of image fusion algorithm.

Analyzing the initial fused image of the source images it will be easy to find that the pixels in the centre range need more amazingly contains information of the relating pixels of the initial source images. The Root Mean Square Error (RMSE) is the distinction (cumulative squared error) between two images. From in turn Perspective, RMSE might measure the comparability of the two images.

RMSE is acquired eventually by calculating each pixel inside a $(2M + 1)(2N + 1)$ window, in the middle of the source image and the initial source images. Then the RMSE values of the source images are compared and can be determine the pixel that is to be focused. When calculating the values of RMSE of source images A and B, if the RMSE value of source image A has more similarity to the pixel of the fused image then the pixel A is more likely to that in the focused area and vice versa.

A initial map is formed from the binary image because the binary image cannot fully reflect the focused area of the source image. It is not necessary that the RMSE value in the focused area should be smaller because of the complexity and limitations of the source images. So, the miscalculations results in the form of holes, bugs, black spots etc in the initial map. So, in order to avoid these miscalculations and imperfections the initial map undergoes certain mathematical morphological functions and the decision map is obtained. For the employment of the mathematical morphological process the following steps have to be considered.

Step 1: To remove the black holes use the imfill filter and thus the black holes can be avoided.

Step 2: The morphological closing is employed to join the small bugs and fill the gap.

Step 3: To remove the black areas that cannot be avoided in step 1 can be avoided using the filter bwareaopen. Here, the threshold is calculated and the threshold value depends mainly on the size of the image.

B. *The Framework of the Proposed Image Fusion Method*

A novel hybrid method based on NSCT and focused area detection is introduced to overcome the disabilities in transform domain and spatial domain methods. The proposed method can be memorized as, the source images fused with the NSCT algorithm divides into low frequency and high frequency coefficients. Then the low frequency coefficients are combined using fusion rules using SML and high frequency coefficients are combined using the fusion rule using the Log-Gabor filter. Then using the inverse NSCT algorithm the initial image is obtained.

This initial fuse image may lose useful information because of several decomposition and reconstruction. So in order to make sure that the useful data aren't lost, focused area detection is followed. By taking the pixels from decision map and source images the final fused image is obtained. Thus, an image with useful information and providing accuracy in human operation is produced.

VI. CONCLUSION

A novel image fusion method that depends on NSCT and focused area detection is proposed for multi-focus image fusion. The potential points of interest of the ace postured technique include: (1) NSCT is more appropriate for image fusion due to superiorities, for example, multi-resolution, multi-direction, and shift invariance; (2) utilizing the detected focused area as a fusion decision map to direct the combination procedure decreases the many sided quality of the methodology as well as expands the dependability and strength of the fusion results; and (3) the proposed combination plan can avert ancient rarities and wrong outcomes at the limit of the engaged ranges that might be presented by focused area detection based strategies amid the image fusion methods. The test comes about on a few gatherings of multi-fusion images, paying little mind to whether there is clamor or not, have demonstrated the prevalent execution of the proposed combination conspire. The NSCT calculation is time consuming and of high complexity, so the following stride that will be contemplated is the way to enhance the speed of the calculation

REFERENCES

[1] Y. Jiang and M. Wang, "Image fusion with morphological component analysis," *Inf. Fusion*, vol. 18, no. 1, pp. 107–118, 2014.

[2] S. Li and B. Yang, "Hybrid multiresolution method for multisensor multimodal image fusion," *IEEE Sensors J.*, vol. 10, no. 9, pp. 1519–1526, 2010.

[3] S. Chen, R. Zhang, H. Su, J. Tian, and J. Xia, "SAR and multispectral image fusion using generalized IHS transform based on à trous wavelet and EMD decompositions," *IEEE Sensors J.*, vol. 10, no. 3, pp. 737–745, 2010.

[4] B. Yang and S. Li, "Multi-focus image fusion using watershed transform and morphological wavelet clarity measure," *Int. J. Innovative Comput. Inf. Control.*, vol. 7, no. 5A, pp. 2503–2514, 2011.

[5] I. De and B. Chanda, "Multi-focus image fusion using a morphology-based focus measure in a quad-tree structure," *Inf. Fusion*, vol. 14, no. 2, pp. 136–146, 2013.

[6] V. Aslantas and R. Kurban, "Fusion of multi-focus images using differential evolution algorithm," *Expert Syst. Appl.*, vol. 37, no. 12, pp. 8861–8870, 2010.

[7] S. Li, J. T. Kwok, and Y. Wang, "Multifocus image fusion using artificial neural networks," *Pattern Recognit. Lett.*, vol. 23, no. 8, pp. 985–997, 2002.

[8] J. Tian, L. Chen, L. Ma, and W. Yu, "Multi-focus image fusion using bilateral gradient-based sharpness criterion," *Opt. Commun.*, vol. 284, no. 1, pp. 80–87, 2011.

[9] S. Li, X. Kang, J. Hu, and B. Yang, "Image matting for fusion of multi-focus images in dynamic scenes," *Inf. Fusion*, vol. 14, no. 2147–162, 2013.

[10] B. Aiazzi, L. Alparone, A. Barducci, S. Baronti, and I. Pippi, "Multi-spectral fusion of multisensor image data by the generalized Laplacian pyramid," in *Proc. IEEE Int. Geosci. Remote Sens. Symp.*, Hamburg, Germany, pp. 1183–1185, 1999.

[11] V. S. Petrovic and C. S. Xydeas, "Gradient-based multiresolution image fusion," *IEEE Trans. Image Process.*, vol. 13, no. 2, pp. 228–237, 2004.

[12] S. Li, J. T. Kwok, and Y. Wang, "Using the discrete wavelet frame transform to merge Landsat TM and SPOT panchromatic images," *Inf. Fusion*, vol. 3, no. 1, pp. 17–23, 2002.

[13] M. N. Do and M. Vetterli, "The contourlet transform: An efficient directional multiresolution image representation," *IEEE Trans. Image Process.*, vol. 14, no. 12, pp. 2091–2106, 2005.

[14] Y. Yang, S. Tong, S. Huang, and P. Lin, "Log-Gabor energy based multimodal medical image fusion in NSCT domain," *Comput. Math. Methods Med.*, vol. 2014, 2014, Art. ID 835481.

[15] A. L. da Cunha, J. Zhou, and M. N. Do, "The nonsubsampled contourlet transform: Theory, design, and applications," *IEEE Trans. Image Process.*, vol. 15, no. 10, pp. 3089–3101, 2006.

[16] B. Yang and S. Li, "Multifocus image fusion and restoration with sparse representation," *IEEE Trans. Instrum. Meas.*, vol. 59, no. 4, pp. 884–892, 2010.

[17] X.-B. Qu, J.-W. Yan, H.-Z. Xiao, and Z.-Q. Zhu, "Image fusion algorithm based on spatial frequency-motivated pulse coupled neural networks in nonsubsampled contourlet transform domain," *Acta Autom. Sinica*, vol. 34, no. 12, pp. 1508–1514, 2008.

[18] H. E. Gerhard, F. A. Wichmann, and M. Bethge, "How sensitive is the human visual system to the local statistics of natural images?" *PLoS Comput. Biol.*, vol. 9, no. 1, pp. 1–15, 2013.

[19] J. Yang, "A fingerprint recognition scheme based on assembling invariant moments for cloud computing communications," *IEEE Syst. J.*, vol. 5, no. 4, pp. 574–583, 2011.

[20] G. Qu, D. Zhang, and P. Yan, "Information measure for performance of image fusion," *Electron. Lett.*, vol. 38, no. 7, pp. 313–315, 2002.