Development and Implementation of Image Fusion Algorithm for LR Multispectral and HR Panchromatic Images Using FDCT

Miss. Juie Chopade[1], Prof.A.G.Patil[2]

PG Student[1], Associate Professor[2]
Department of E&TC Engineering, PVPIT,Budhgaon,
Sangli,Maharashtra,India.

Abstract: Image fusion is a procedure of merging several input images into a single output image which encircle better explanation of the view than the one offered by any of the individual input images. The creation and use of an image fusion technique utilizing the Fast Discrete Curvelet Transform (FDCT) to merge high-resolution (HR) panchromatic images with low-resolution (LR) multispectral images is shown in this study. Enhancing high resolution while maintaining various information is the goal of image fusion, which is crucial for a number of satellite or remote sensing applications. The FDCT is used because it can capture directional and multi-scale characteristics, which makes it ideal for fusing pictures of varying resolutions. The efficacy of the suggested approach in enhancing the spatial detail of multispectral pictures without appreciable spectral distortion is assessed using satellite imagery. The FDCT based fusion strategy performs better than other methods, as demonstrated by a comparative study with previous image fusion algorithm like DWT, PCA and IHS.

Keywords—*Satellite Image Fusion, FDCT (Fast Discrete Curvelet Transform), LR-MS (Low Resolution Multispectral Images), HR-PAN (High Resolution Panchromatic Images), DWT (Discrete Wavelet Transform), PCA (Principal Component Analysis).*

1. INTRODUCTION

To obtain more information, the image or photographs must focus everywhere rather than just one thing. These varieties of pictures are convenient for several sectors like robotics, computer vision, satellite remote detecting, digital photography, and microscopic imaging. The restricted deepness of field of photosensitive lenses, especially those through extended focal lengths, is causing problems [1]. One well-known resolution to this problematic situation is image fusion, which permits us to take a series of photographs taken in different locations and fuse or combine these images to create an image by means of complete profundity of field [2].

The Image Fusion (IF) is the development of merging all the applicable data taken after numerous images into a solo image. Compared to a single source image, this one resultant image is extra precise as well as it has all the crucial information. Combining complementary information from many photos of the similar section to create a solitary, superior synthetic image is the aim of image fusion. As a result, it is increasingly applicable to digital camera imaging, military surveillance, remote sensing, and other domains. The general processing stages for all image fusion approaches are depicted in Figure 1.1.

When it comes to satellite imaging, the panchromatic (PAN) image that the satellites take is communicated through the Higher Resolution (HR) feasible, whereas Multi Spectral (MS) information of the picture is given with a Lower Resolution (LR). This resolve often be reduced by three or four times. Next to the receiving station, the panchromatic image data and the multispectral data are merged to send further data. A panchromatic picture is a black and white (B&W) construction of an image taken in the comprehensive visible wavelength series. Multispectral images are those that have been optically captured in many wavelengths or spectrums. While the spectral band changes, each individual image's physical dimensions and scale are frequently the same.

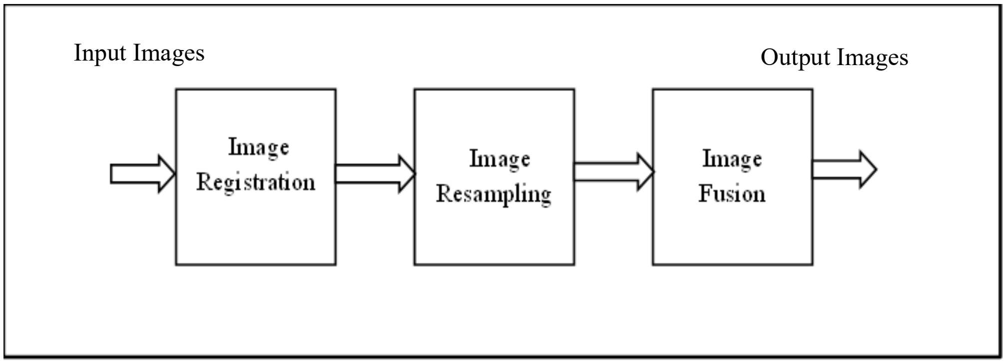

Figure 1.1: General processing stages of image fusion techniques

This work aims to assess and implement the fusion strategy for satellite photos and demonstrate how our approach can preserve the original image's superior spectral as well as spatial abilities at the similar time. The process of merging data for photograph investigation, feature abstraction, modelling, and organization the data when the it is received with different spatial and spectral resolutions is acknowledged as remote sensing image or picture fusion [6]. The ability to decode the spectral statistics of rough scale multispectral data to a better scale of the pan image by means of negligeable spectral twist outline has been demonstrated by image fusion techniques that rely on inserting high frequency mechanisms engaged through PAN image into resample varieties of the multispectral information [8]. In this work, we proposed an image fusion technique that works with Low Resolution Multispectral (LRMS) images and High Resolution Panchromatic (HRPAN) images using the FDCT algorithm, yielding highly efficient results.

2. LITERATURE SURVEY

Every previous work that was looked at throughout the work is described in depth in this chapter. This section thoroughly examines previous research, which is important for satellite image fusion. Additionally, this data is utilized in a similar method for FDCT purposes in the satellite image fusion process. A substantial amount of effort has been put into understanding the various methods used in picture fusion of interframes of satellite-captured images, according to this literature review.

Researcher C.V.Rao, J. Malleswara Rao, A.Senthil Kumar, D.S.Jain, V.K.Dadhwal in 2014 have studied various methods on image fusion and introduces new image fusion techniques using Fast Discrete Curvelet Transforms (FDCT), specifically in the context of satellite imagery [1]. To progress the excellence of fused satellite broadcasting pictures, particularly once combination high resolution panchromatic images with lower resolution multispectral images, the authors suggested an approach that makes use of the curvelet transform, a sophisticated method in multiscale and directional image decomposition. The work provided us with an effective technique for fusing satellite images: the Curvelet Transform. Curvelets are perfect for high-resolution satellite photos because, in contrast to wavelet transformations, they better represent images with edges and features. In remote sensing applications where edge preservation and spatial resolution are essential, curvelets are very good at collecting both small features and edge information. These authors emphasized the need of computational efficiency, particularly for big datasets of satellite images, which demand a lot of processing time and power when using more conventional techniques like wavelets.

In March 1999 Zhang Z, Blum R.S, developed method that which is founded on multiscale decomposition, particularly for applications in digital cameras [2]. The authors classify several fusion strategies and assess how well they work when combining pictures with varying spectral and spatial resolutions. Based on the decomposition mechanism employed, they categorized multiscale decomposition-based fusion techniques. This classification aids in comprehending various strategies and contrasting their advantages and disadvantages. To evaluate the efficacy of several multiscale decomposition-based fusion techniques, they also looked at a performance. Based on objective standards including spatial resolution, spectral quality, and visual quality, the study compared the quality of fused pictures. Particularly for real-world applications where both spatial and spectral features are essential, the authors stressed the significance of assessing these approaches' performance using both objective and subjective measures.

Li S, Kwok J, Tsang I, Wang Y, in 2004 focused on the problem of image fusion where multiple images of the similar passage are captured at different focal lengths (focus levels) [3]. This is a prevalent problem in many imaging applications, including photography, surveillance, and medical imaging (e.g., microscopy), where certain features may be sharply focused in one picture while others are hazy or out of focus in another. Using Support Vector Machines (SVMs), they presented a novel method for image fusion, especially in situations when several pictures of the same scene are taken with varying degrees of focus. Complex image fusion tasks may be handled well with SVMs, improving the fused picture's sharpness and clarity. In terms of fusion quality, the method was demonstrated to perform better than conventional approaches, which makes it a potential methodology for a series of image processing and computer vision applications.

3. IMPLEMENTED ALGORITHM

In this research paper, we have used images of engineering college named Padmabhooshan Vasantraodada Patil Information Technology which is situated near the Budhgaon village in Sangli district of Maharashtra state shown in fig. 1 indicates that LR-MS has low resolution and size of 95 MB and HR-PAN image is of 120 MB as well as we have gathered few satellite images from google earth with different sizes and various image format like *.tiff, *.png, *.jpeg etc. There have been two significant updates to the curvelet transform. The ridge let analysis of random transform of an image was one of the many procedures involved in the first generation curvelet transform. The performance was sluggish. By doing away with the ridge let transform, the second generation curvelet transform significantly boosted speed and decreased redundancy in the transform. There were two quick discrete curvelet transform algorithms shown. While the second approach is based on the wrapping of specifically chosen Fourier samples, the first algorithm relies on uneven spacing.

Figure No. 2 LR-MS and HR-PAN images of PVPIT Engg. College

The algorithm is implemented in MATLAB programming software along with curvelab 2.3 version. The aim is to generate a satisfactory algorithm for satellite image fusion of LR multispectral images and HR panchromatic images using Fast Discrete Curvelet Transform. A GUI is produced to compose a "consumer friendly" interface for newly successful n effective exhibition of the applied algorithm and results.

The algorithm implemented includes numerous stages that are incorporated mutually. The whole process flow is as exposed in Figure 3.

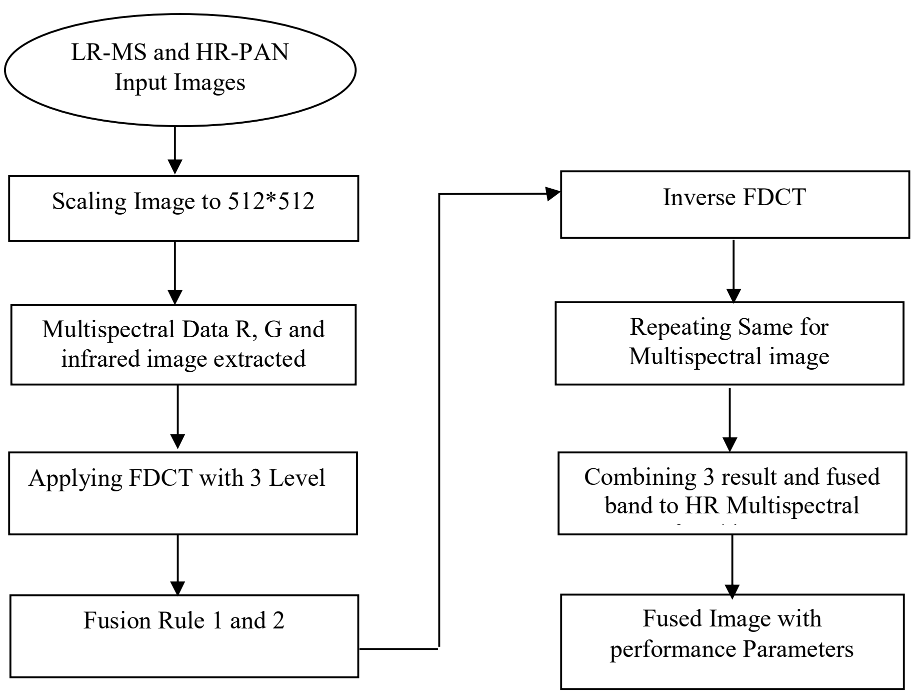

Figure No. 3. Flowchart of proposed system

a. Input Images: Multispectral Image (MS) and Panchromatic Image (PAN) are the inputs. MS is lower resolution with spectral information, and PAN is a high-resolution image that lacks spectral information.
b. Preprocessing: Align the images (MS and PAN) to ensure they are spatially aligned before fusion.
c. Fast Discrete Curvelet Transform (FDCT): Transform the MS image into curvelet coefficients using FDCT to capture multi-scale directional information. Similarly, apply FDCT to the PAN image to extract the high-frequency details.
d. Fusion Rule (Coefficient Merging):
   Low-Frequency Coefficients- Apply an appropriate fusion rule to merge low-frequency components, which typically contain spectral information.
   High-Frequency Coefficients- Use another fusion rule to combine high-frequency coefficients, as these contain spatial details.
e. Inverse FDCT: Apply the inverse FDCT to the merged coefficients to reconstruct the fused image with both high spatial resolution and spectral fidelity.
f. Repeat the procedure and combine three resultant fused bands to get high Resolution multispectral fused image and calculate entropy of High-Resolution output image.

4. EXPERIMENT AND RESULT

4.1 Entropy:

The Entropy can show the average information included in the image and reflect the detail information of the fused image.

$$E = -\sum_{i=0}^{L-1} P_i \log_2 P_i \qquad (1)$$

Where *E* is the entropy of image and *pi* is the probability of *I* in the image, here *pi* is the frequency of pixel values from 0 to n in the image. Entropy values band wise are shown in Table 1

FDCT	Wavelet	PCA
7.3971	6.21	6.23

. **Table 1. Entropy**

4.2 Peak Signal-to-Noise Ratio (PSNR):

PSNR measures the ratio between the maximum possible pixel value and the power of the noise that affects the image quality. It is used to assess the quality of the fused image compared to the original image.

$$\text{PSNR} = 10 log_{10}\left(\frac{MAX^2}{MSE}\right) \qquad (2)$$

Where, MAX is the maximum possible pixel value of the image (e.g., 255 for 8-bit images) and MSE is the mean squared error between the source and fused image. Higher PSNR values indicate better image quality and less distortion introduced by the fusion process.

4.3 Correlation Coefficient (CC):

Correlation Coefficient quantifies the similarity between the spectral content of the fused image and the original image. High frequency details from the Pan image are compared to the high frequency details from each band of the fused images using a method proposed.

$$\rho = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left[F(x_i, y_j) - f\right]\left[A(x_i, y_j) - a\right]}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}\left[F(x_i, y_j) - f\right]^2\left[A(x_i, y_j) - a\right]^2}} \tag{3}$$

Where $F(x, y)$ is the pixel grey value of merged image, f is the mean value of merged image, $A(x, y)$ is the pixel grey value of original image, and a is the mean value of original image.

FDCT	Wavelet	PCA
0.99502	0.18	0.77

Table 2: Correlation Coefficient

We compared FDCT image fusion technique with previous methods using performance metrics of fused satellite image. Table no. 6 shows comparison of previous methods with different metrics.

5. CONCLUSION

FDCT is a theoretically simpler, quicker, and significantly less redundant solution than previous curvelet-based implementations. According on the experimental data, the Fast Discrete Curvelet Transform outperforms the other techniques. When compared to previous fusion procedures, the fusion rule produces a merged picture with superior spectral and spatial quality. Compared to earlier techniques like DWT, PCA, and IHS approaches, this approach produced superior results. Fast Discrete Curvelet Transform (FDCT) satellite image fusion offers a identically efficient way to improve the quality and understanding of satellite pictures. Urban planning, environmental monitoring, and disaster management are just a few of the applications that benefit greatly from the FDCT algorithm's ability to effectively capture and depict edges and other singularities in the picture. However, to further improve fusion accuracy and applicability across other domains, future research might concentrate on hybrid systems that combine FDCT with other techniques like machine learning. All things considered, FDCT-based satellite image fusion greatly enhances picture interpretation and analysis, making it a useful tool for geospatial analysis and remote sensing

6. ACKNOWLEDGMENTS

This research was supported under the department of electronics and telecommunication of PVPIT, Budhgav College, Sangli. For this work my guide Prof. A.G. Patil gave valuable information with effective guidance. I am very thankful to my Head of Department Mr. M.S. Chavhan Sir ang Principal Mr. B. S. Patil Sir.

REFERENCES

[1] Zhang, Z., Blum, R.S., 1999. ―A categorization of multiscale-decomposition- based image fusion schemes with a performance study for a digital camera application‖. Proc. IEEE 87 (8), 1315–1326.

[2] Li, S., Kwok, J., Tsang, I., Wang, Y., 2004. ―Fusing images with different focuses using support vector machines‖. IEEE Trans. Neural Networks 15 (6), 1555– 1561.
[3] Cande`s, E.J., Donoho, D.L., 2000. ―Curvelets – A surprisingly effective non adaptive representation for objects with edges‖. In: Rabut, C.,
Cohen, A., Schumaker, L.L. (Eds.), Curves and Surfaces. Vanderbilt University Press, Nashville, TN, pp. 105–120
[4] Cande`s, E.J., Demanet, L., Donoho, D.L., Ying, L., 2006. ―Fast discrete curvelet transforms. Multiscale Model. Simul. 5 (3), 861–899.
[5] http://www.curvelet.org
[6] C. Pohl, J.L. van Genderen, ―Multisensory image fusion in remote sensing: concepts, methods, and applications‖, International Journal of Remote Sensing 19 (5) (1998) 823 854.
[7] A.S. Kumar, B. Kartikeyan, K.L. Majumdar, ―Band sharpening of IRS-multispectral imagery by cubic spline wavelets‖, International Journal of Remote Sensing 21 (3) (2000) 581–594.
[8] L. Wald, T. Ranchin, M. Mangolini, ― Fusion of satellite images of different spatial resolutions: assessing the quality of resulting images, Photogrammetric Engineering and Remote Sensing 63 (6) (1997) 691–699.
[9] J.L. Starck, E.J. Cande`s, D.L. Donoho, ―The curvelet transform for image denoising‖, IEEE Transactions on Image Processing 11 (6) (2002) 670–684
[10]M.N. Do, M. Vetterli, ―The finite ridgelet transform for image representation‖, IEEE Transactions on Image Processing 12 (1) (2003) 16–28.
[11] T. Ranchin, L. Wald, ―Fusion of high spatial and spectral resolution images: the ARSIS concept and its implementation‖, Photogrammetric Engineering and Remote Sensing 66 (1) (2000) 49–61.
[12] A. Garzelli, F. Nencini, ―Interband structure modelling for Pan sharpening of very high resolution multispectral images‖, Information Fusion 6 (3) (2005) 213–224.
[13]M. Choi, R.Y. Kim, M.-R. Nam, H.O. Kim, ―Fusion of multispectral and panchromatic satellite images using the curvelet transform‖, IEEE Geosciences and Remote Sensing Letters 2 (2) (2005) 136–140.
[14]C.V.Rao, J.Malleswara Rao, A.SenthilKumar, D.S.Jain, V.K.Dadhwal, ―Satellite Image Fusion Using Fast Discrete Curvelet Transforms‖, Hyderabad, India, IEEE, 2014c
[15] C.V.Rao, J. Malleswara Rao, A.Senthil Kumar, D.S.Jain, V.K.Dadhwal, satellite image fusion using Fast Discrete Curvelet Transforms, National Remote Sensing Centre, Indian Space Research Organization, Hyderabad,IEEE 2014