# Performances analysis of DWT for Image Compression, Registration and Fusion Techniques Using DWT in Micro Air Vehicle Applications

Venkasteshappa**,** Dr. Cyril Prasanna Raj P.

**Abstract** — Micro Air Vehicle (MAVs) will play a vital role in home land security, remote sensing and surveillances. Cameras mounted on different MAVs collect various images from various angles and hence have to be registered and fused to extract maximum information. Every image captured when transmitted would occupy huge bandwidth and storage space. Thus compression, registration and fusion are three important image processing techniques that are required to be used in MAVs for accuracy and reliability. In this paper, we analyze the performances of all the three technique based on DWT. Various wavelet filters are used for analysis of image processing technique. The total computation time, MSE and PSNR are estimated for DWT based image processing. Software reference model is developed using Simulink and Matlab for analysis. Based on the results obtained, it is found that DWT based image processing achieves higher PSNR, MSE and also lower computation time and hence is suitable for MAV applications.

**Index Terms** — Micro Air Vehicle, Image fusion, DWT for imaging, Image Registration, Image Compression

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## 1 INTRODUCTION

Data fusion is an effective way for optimum utilization of large volumes of data from multiple sources. Multi-sensor data fusion seeks to combine information from multiple sensors and sources to achieve inferences that are not feasible from a single sensor or source. The fusion of information from sensors with different physical characteristics enhances the understanding of our surroundings and provides the basis for planning, decision-making, and control of autonomous and intelligent machines [Jin, X.Y.; Davis, C.H.]. In the past decades it has been applied to different fields such as pattern recognition, visual enhancement, object detection and area surveillance [Molch K., 2010]. Data fusion is a process of combining images, obtained by sensors of different wavelengths to form a composite image. The composite image is formed to improve image content and to make it easier for the user to detect, recognize, and identify targets and increase situational awareness. Multi-sensor data fusion can be performed at four different processing levels, according to the stage at which the fusion takes place: signal level, pixel level, feature level, and decision level. Figure 1 illustrates the concept of the four different fusion levels [Dong Jiang,].

In a swarm of MAVs, where in multiple MAVs surveillance remote areas, images are captured and compressed and transmitted to the base station. MAVs that surveillance common area, gather the data from a same location using different type of sensors. The image captured can be IR image from one sensor and visible image from another sensor. The capture time and angle may be different. Hence it is required to register the decompressed images at the base station and fuse the image to extract maximum
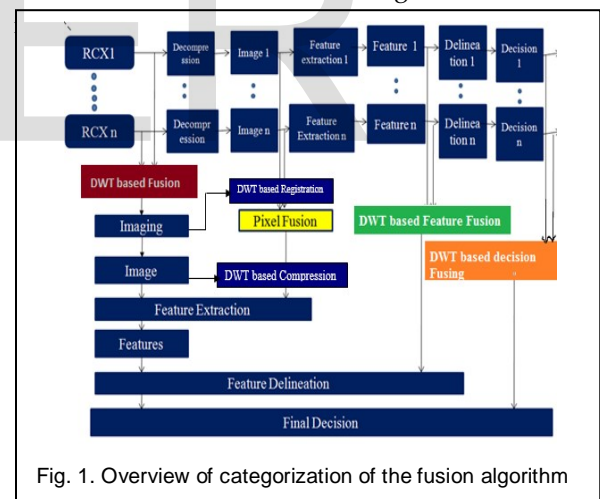


Fig. 1. Overview of categorization of the fusion algorithm

As in Figure 3, compressed images reach the base station receiver, the received image is fused prior to decompression and fusion is performed. The received compression image is decompressed and feature extraction is performed. Features are extracted and features are fused. Based on features, decision is extracted and decision is fused. Images to be fused need to be registered; hence registration is one of the major techniques to be performed prior to fusion. 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 performed on a pixel-by-pixel basis. It generates 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-based fusion at feature level requires an extraction of objects recognized in the various data sources. It requires the extraction of salient features which are depending on their environment such as pixel intensities, edges or textures. 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 multiple algorithms to yield a final fused decision. Input images are processed individually for information extraction.

The obtained information is then combined applying decision rules to reinforce common interpretation. Among the hundreds of variations of image fusion techniques, the most popular and effective methods include, but are not limited to, intensity-hue-saturation (IHS), high-pass filtering, principal component analysis (PCA), different arithmetic combination (e.g., Brovey transform), multi-resolution analysis-based methods (e.g., pyramid algorithm, wavelet transform), and Artificial Neural Networks (ANNs). In this paper, compression, fusion and registration of image/video sequence is performed using DWT.

## 2 WAVELET BASED IMAGE FUSION

Multi-resolution or multi-scale methods, such as pyramid transformation, have been adopted for data fusion since the early 1980s [11]. The Pyramid-based image fusion methods, including Laplacian pyramid transform, were all developed from Gaussian pyramid transform, have been modified and widely used, and substituted by the wavelet transform methods in some extend in recent years [12, 13]. The Figure 2 shows the top level application block diagram of image fusion using wavelet transform which consists of two registered images, discrete wavelet transform block, fusion block and inverse wavelet transform block.
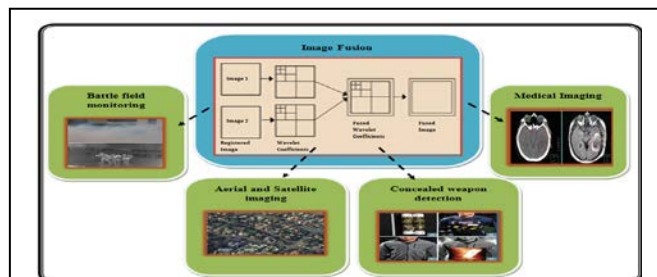


Fig. 2. **Top level application block diagram of image fusion**

## 3 DWT FOR IMAGING

The two-dimensional DWT is becoming one of the standard tools for image fusion in image and signal processing field. The DWT process is carried out by successive low pass and high pass filtering of the digital image or images. This process is called the Mallat algorithm or Mallat-tree decomposition. Figure 3 shows an implementation structure of the DWT-IDWT.
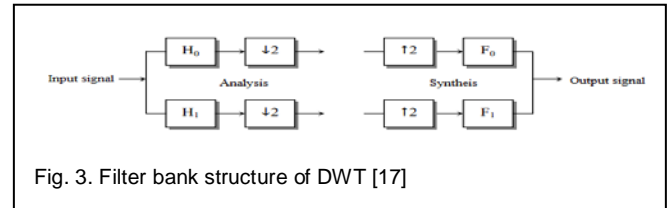


Fig. 3. Filter bank structure of DWT [17]

The filter coefficients of high pass and low pass sub bands need to satisfy the property are shown in Eq. 1 and Eq. 2 respectively for perfect reconstruction.

$$\frac{1}{2}\left[H_0\left(Z^{\frac{1}{2}}\right)X\left(Z^{\frac{1}{2}}\right)+H_0\left(-Z^{\frac{1}{2}}\right)X\left(-Z^{\frac{1}{2}}\right)\right] \quad (1)$$

$$\frac{1}{2}\left[H_1\left(Z^{\frac{1}{2}}\right)X\left(Z^{\frac{1}{2}}\right)+H_1\left(-Z^{\frac{1}{2}}\right)X\left(-Z^{\frac{1}{2}}\right)\right] \quad (2)$$

For processing 2-Dimensional signals such as images, the original image is passed through low pass and high pass filter for first level decomposition. The transformed image is transformed further passed through a pair of low pass and high pass filters to achieve 2 level decomposition of original image as shown in Figure 4.
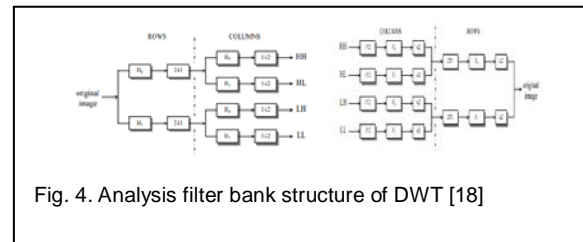


Fig. 4. Analysis filter bank structure of DWT [18]

Pyramid decomposition is generated by successive application of decomposition to the LL sub band where the sub images correspond to different resolution levels and orientations as exemplified in Figure 5. From the images shown in Figure 5, we find that the LL component in the first level decomposition and the LLL component in the second level have the same information with different resolutions. DWT plays a vital role as the information available at various sub bands can be effectively used in

image registration, compression and fusion. Next section discusses design of software reference model for DWT and fusion.

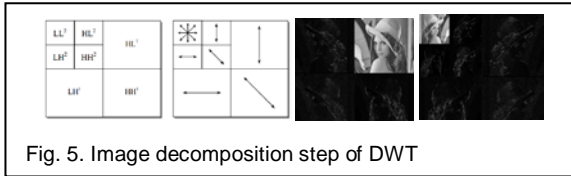The Figure 5 shows the pyramid decomposition of an image (Canaga 2002).



Fig. 5. Image decomposition step of DWT

## 4  DWT BASED IMAGE FUSION

The requirement for the successful image fusion is that images have to be correctly aligned on a pixel-by-pixel basis. In this project, the images to be combined are assumed to be already perfectly registered. The Figure 6 shows the top level block diagram of image fusion using wavelet transform. The two input images image1and image 2 that are captured from visible and infrared camera respectively are taken as inputs. The wavelet transform decomposes the image into low-low, low-high, high-low, high-high frequency bands. The wavelet coefficients are generated by applying the wavelet transform on input images. Wavelet coefficients of the input images are fused by taking the average of input images. The resultant fused image is obtained by applying the inverse wavelet transform.
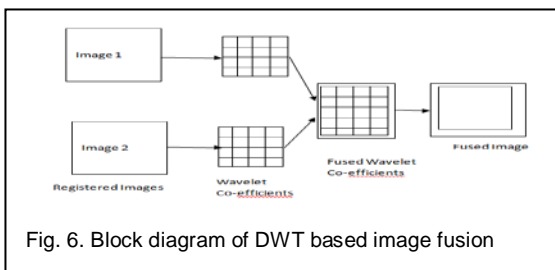


Fig. 6. Block diagram of DWT based image fusion

The wavelet transforms of the images has been computed. The registered images have been passed as input signals through two different one-dimensional digital filters H0 and H1 respectively. H0 and H1 digital filters perform high pass and low pass filtering operations respectively for both the input images. The output of each filters are followed by sub-sampling by a factor of 2. This step is referred as the Row compression and resultant is called as L-low frequency component and H-high frequency component. The down sampled outputs have been further passed to two one dimensional digital filters in order to achieve Column compression. The HH-High High, HL-High Low, LH-Low High and LL-Low Low are the output frequency

components obtained after two level compressions of both the input images.

The Figure 7 shows the block diagram of DWT based image fusion process which consists of two input images, DWT block, fusion block and IDWT block. The HH, HL, LH and LL frequency components of one input image is fused with the HH, HL, LH and LL components of second image respectively. HH components of both images have been added and then the resultant output has been divided by a factor 2. Similarly, the average of HL, LL and LH components has been taken. This process is known as Image Fusion. This averaged result has been future followed by the reconstruction process i.e., inverse wavelet transform. IDWT is the reverse process of DWT. In IDWT process, the HH, HL, LH and LL components have been first up-sampled and then filtering operation has been carried out. The sub-bands has been added or summed to get the resultant reconstructed image. The DWT based image fusion technique produced the more naturally fused image even when the images to be combined have been taken from different cameras. The results obtained by the image fusion techniques by using averaging, Haar-DWT, biorthogonal-DWT and 9/7 Daubechies-DWT for first set of images have been tabulated in Table 1.  High performance, good clarity fused image has been obtained by using 9/7 Daubechies filter based image fusion technique.
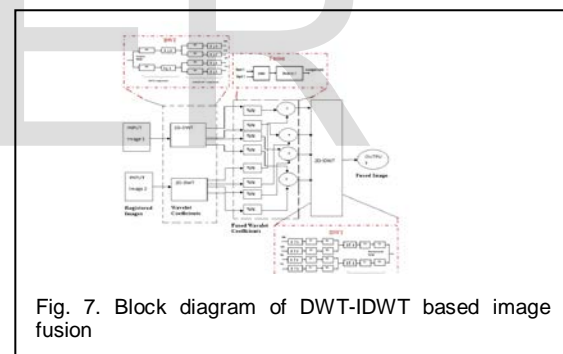


Fig. 7. Block diagram of DWT-IDWT based image fusion

## 5  DWT BASED IMAGE REGISTRATION

Image registration is the mapping of spatial coordinates from one image to corresponding points in the other image and it is a primary step before image mosaic or image fusion. Registration can be performed manually and automatically.
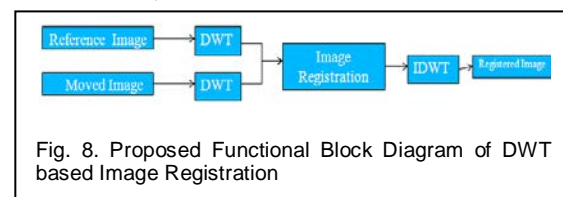


Fig. 8. Proposed Functional Block Diagram of DWT based Image Registration

Image registration can be classified as area based, feature based, search based, direct based, spatial domain methods,

frequency domain methods, single modality and multi-modality. These are the methods to find the spatial points and map it. In this project the discussion is mainly about the wavelet based image registration technique. Figure 8 shows the image registration process using DWT.

The inputs to the image registration are reference and moving image. If it is a three dimensional image, one of the component is taken. This component can be red, blue or green which depends upon the brightness of the image. In this work blue component of the image is used and an initial scaling condition is also assigned. This scaling condition is assigned for a higher scale so that in every rotation the image is reduced in size. Each time when it passes through the function its scaling parameters are changed and a new rotation and translation matrix is formed according to the scaling condition. This rotation and translation matrix is used for the affine transformation and a linear interpolation is applied to match the pixels at non grid positions. After that it passed into correlation metric where a correlation is found whether it is nearing to 1 or not. If it is not nearing 1 then the scaling parameter is again decreased and the new matrix is again formed for the affine transformation. This process is repeated until it reaches closer to 1 in the metric. The Figure 9 shows the Image registration results using DWT. The images are captured at various time intervals, DWT is computed and significant points in the LL sub bands are chosen, the translation, rotational and skewness among these points as compared with the reference image is identified, and the displaced image is rotated or translated. Registration is carried out in the transformed domain and IDWT is performed.



Fig. 9. Image registration results using DWT

# 6 DWT BASED IMAGE COMPRESSION

Lossy image compression can provide acceptable image quality while also providing dramatic reductions in image size. In wavelet transforms, the original signal is divided into frequency resolution and time resolution contents. The decomposition of the image using 2-level DWT is shown in Figure 10.
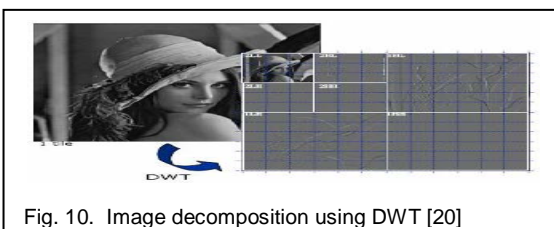


Fig. 10. Image decomposition using DWT [20]

As shown in the figure, input image consisting rows and columns are transformed using high pass and low pass filters. The filter coefficients are predefined and depend upon the wavelets selected.

The Figure 11 shows the Simulink mode for image compression using DWT. The Simulink model consists of an input image that is a color image which consists of RGB components, which are separated and are resized. The resized image is transformed into four sub bands using DWT, from the 12 sub bands obtained for RGB components, only the LL sub band is chosen and is inverse transformed. All the other sub band components are multiplied by zero and hence eliminated during the reverse process. This would degrade the image quality, however, as the requirement is in MAV applications it is required to reduce image size before transmission. Transmission of LL sub band would provide better results.
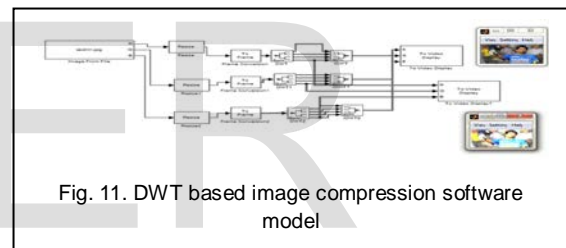


Fig. 11. DWT based image compression software model

# 7 RESULTS AND SIMULATION

The results obtained by the image fusion techniques by using averaging, Haar-DWT, biorthogonal-DWT and 9/7 Daubechies-DWT for second set of images has been tabulated in Table 1.

High performance, good clarity fused image has been obtained by using 9/7 Daubechies filter based image fusion technique. The results obtained by the image fusion techniques by using averaging, Haar-DWT, biorthogonal-DWT and 9/7 Daubechies-DWT for third set of images has been tabulated in Table 1. High performance, good clarity fused image has been obtained by using 9/7 Daubechies filter based image fusion technique.

The Table 2 shows the PSNR values for the existing model and the developed 9/7 Daubechies filter based image fusion. The 9/7 Daubechies based image fusion has achieved same PSNR when compared with the existing model.

TABLE 2

PERFORMANCE COMPARISON OF EXISTING VS. OBTAINED
IMAGE FUSION

| Input Images | PSNR | |
|---|---|---|
| | Existing | Proposed |
| Image set 1 | 150 | 170.83 |
| Image set 2 | 128 | 168.85 |
| Image set 3 | 148 | 168.56 |
| Image set 4 | 132 | 170.92 |
| Image set 5 | 141 | 166.2 |
| Image set 6 | 156 | 172 |
| Image set 7 | 178 | 18 |

Table 3 presents DWT based image registration results. From the results obtained it is found that, DWT based registration is faster than spatial domain registration. Using all the four sub bands produce better PSNR but consumes more time. Advantages of registration are that the registration process consumes very less time.

TABLE 3

IMAGE REGISTRATION RESULTS

| LL | LH | HL | HH | PSNR | Computation time in sec |
|---|---|---|---|---|---|
| S | S | S | S | 52 | 5.12 |
| S | S | S | NS | 50 | 4.92 |
| S | S | NS | NS | 48 | 4.8 |
| S | NS | NS | NS | 48 | 4.1 |

TABLE 4

DCT VS. DWT COMPARISON FOR IMAGE COMPRESSION

| Images | MSE DWT | MSE DCT | PSNR DWT | PSNR DCT |
|---|---|---|---|---|
| Trees | 21 | 31 | 36 | 31.5 |
| Board | 18 | 22 | 41 | 32 |
| Circuit | 16.9 | 21 | 43 | 37 |
| Greens | 12.7 | 27 | 51 | 43 |
| Football | 18 | 21 | 42 | 35 |
| Cameraman | 17 | 23 | 39 | 32 |
| Tape | 19.8 | 31 | 38 | 31.4 |
| Fabric | 15 | 23 | 42 | 33.5 |
| Pears | 14.34 | 19 | 38 | 32.6 |
| Saturn | 27 | 39 | 34 | 27 |
| Peppers | 22 | 31 | 32 | 26 |
| Tier | 27 | 41 | 37 | 31.2 |
| Kids | 38 | 53 | 30 | 22.4 |
| Rice | 25.4 | 35 | 39 | 27.6 |
| cell | 45.7 | 62 | 42 | 26 |

In this work, 9/7 wavelets have been used for constructing the filters. Software reference model is developed to analyze image compression using DWT. Input image is rescaled into 100 x 100 and is processed using DWT and IDWT algorithm. Decomposed sub-band components are selected to achieve different compression ratios. MSE and PSNR are the two parameters that are used to analyze the DWT performances. The results of the same are compared with DCT based compression techniques and are shown in Table 4.

From the results obtained and presented in table 4 obtained for a compression ratio of 50, DWT based compression out performs DCT based compression. The software model developed for DWT based compression consists of DWT and SPIHT. For DCT based compression, run length coding and Huffman coding is used. With DWT providing better results in terms of MSE and PSNR, in this work, DWT is used for registration, fusion as well as compression. Figure 11 shows the software results of DWT based compression using DWT.
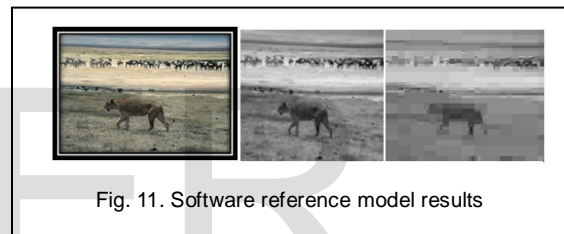


Fig. 11. Software reference model results

The following table 5 shows the comparison of the images obtained after applying DWT and IDWT algorithms and also gives out the PSNR values for different compression ratios.

TABLE 5

**DCT vs. DWT comparison for image compression**



| Compression Ratio | Original Image | After DWT | After IDWT | PSNR |
|---|---|---|---|---|
| 0 | | | | 9.762 |
| 25 | | | | 9.807 |
| 50 | | | | 9.808 |
| 75 | | | | 9.822 |

## 8 CONCLUSION

In this paper, three very important image processing techniques such as image compression, image registration and image fusion are discussed. Importance of these three techniques in MAVs is presented. All the three techniques are performed using DWT. Software Simulink model for DWT based image compression, image registration and image fusion is developed. Various wavelets filters such as Haar, Daubechies and biorthogonal are used for fusion, registration and compression. MSE, PSNR and computation time is computed using the Simulink model. The sub band components obtained are used for fusion, registration and compression. In fusion and Registration LL sub band component of both images are used for fusion and registration, after which inverse DWT is computed to obtain the registered and fused image. In compression, the three sub band components like LH, HL and HH are eliminated and only the LL component is used for decompression. The software model developed help in analysis of performances of DWT based image processing technique. The processing delay of DWT is reduced by 50% compared with generic lifting based DWT. The high speed processing DWT is suitable for MAV applications and can be used for registration, fusion and compression. The hardware model for DWT can be developed for real time implementation optimizing for area, power and speed performances.

## ACKNOWLEDGEMENT

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## AUTHORS

Venkateshappa, Research Scholar is currently pursuing doctoral degree in VTU, Belgaum, Karnataka, India, M No+91-9980261535, venkat_harishith@rediffmail.com

Dr. Cyril Prasanna Raj P, Dean (R&D)and Professor in Dept. .Of ECE , M.S. Engineering College, Bengalur, Karnataka, India, M No +91-9448686332, Cyril@msec.ac.in