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# Image Fusion for Wireless Sensor Networks

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**ABSTRACT:** Wireless Sensor Networks (WSN) have energy, bandwidth and computational constraints. Major source of energy consumption is transmission of image from source to sink and image processing at the nodes. The captured image at the source could be noisy, incomplete and redundant. Hence, images can be fused at the closer by neighbors and fused image is routed to the to sink provided they have correspondence to previously received image. Fused image free of redundancy, brings out complementary features and aids in further analysis. This paper brings out the energy and computational time aspects of fusion algorithms in WMSN for averaging, select maximum, PCA, DCT, DWT, SWT.
***Keywords:*** WMSN, image fusion, SVD, DWT

## Introduction

Internet of things (IoT) is the buzzword that is awaited to do the real magic to the human kind. WSNs indeed would be integral part of IoT. WSNs have plenty of applications like temperature sensing, landslide detection, automated parking, medical diagnosis, machine maintenance, disaster management etc [1]..A typical WSN application involving image transmission is shown in Fig.1 WSN with vision (camera equipped nodes) along with many more integrated sensors like microphones form the class of Wireless Multimedia Sensor Networks (WMSN). WMSNs have unfolded new class of applications like intruder detection, surveillance etc [2].

WSNs face energy, bandwidth, memory, computational crisis because of the demanding applications which force them trade-off many sophistications. Image fusion has proven to be an indispensable tool for remote sensing and medical imaging. In the recent years image transmission in WSN was a challenging task, and many authors have done good deal of work to transmit image using compression. But along with compression we can combine fusion since processing power of nodes is ample enough in the recent WSN technology. In this paper we discuss the effect of choosing the particular fusion algorithm on latency and energy consumptions.

The rest of the paper is organized as follows. Section II gives briefs out the related work done in image fusion and image processing in WSN. Section III covers implementation of the algorithms. Section IV gives the account of WSN and image fusion evaluation parameters along with network model considered. Section V is the simulation results and discussion followed by conclusion and scope for future work in section VI.

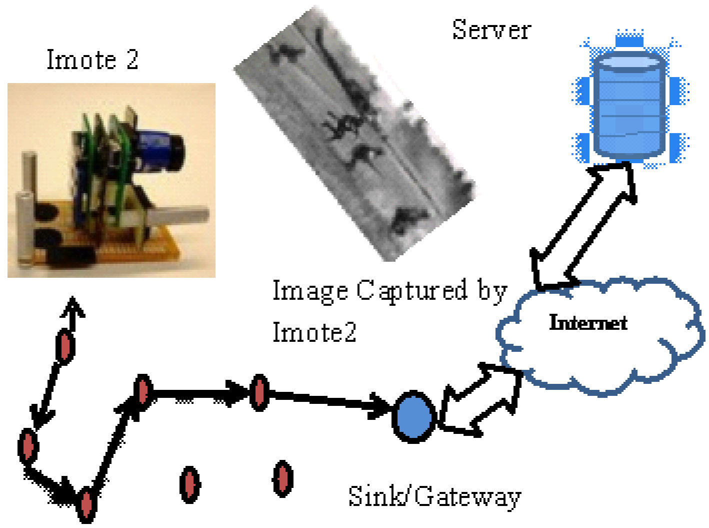


Figure 1. A typical WSN application involving image acquisition

## Related Work

Though we don't find exclusive literature on image fusion techniques in WSN, there have been works on energy efficient image transmission which involve compression and image fusion. Manvi et al,. [7], proposed a Context Aware agent based Distributed Sensor Network (CADSN) to form an improved infrastructure for multi-sensor image fusion to monitor the militant activities. The proposed work is based on context aware computing which uses software mobile agents for image fusion in WMSN. Instead of each source node sending sensed images to the sink node, images from the different active nodes are fused using DWT and sent to sink node by using mobile agent. MinWu et al, used a shape matching method based image fusion [8] assuming that background is not going to change over the desired interval. In that proposed work background is transmitted only once to the sink and later on only the changes are encoded and sent to sink. In the sink the background and change received is fused. What kind of fusion technique is used are not stated. Nasri, et al[9] have adopted distributed image compression taking advantage of JPEG 2000 still image compression which optimizes network life time and memory requirements but not considered fusion aspect. Image fusion is popular in image processing since many years and we can find exclusive literature [3], [4], [5], [6].

## The Image Fusion Algorithms

Image fusion is the process of combining the information from two or more image data into a single integrated useful image. It is assumed that images are compressed before transmission and decompressed before fusion. It is also assumed that images are registered and each of the selected nodes has images ready to be fused. Let imag1, imag2 to be the test images to be fused and fused_imag is the fused image.

## Averaging and Select Maximum

Averaging technique is an elementary method wherein we compute average of two images at pixel level given by

fused_imag (i, j) =(imag1(i, j)+imag2(i, j))/2

However it yields reduced contrast but can be useful in WSN in certain occasions like to supplement the detection of metal gun by metal detectors.

Select maximum too is a very old fusion method wherein we compute fusion by selecting the maximum value of two images at pixel level given by

fused_imag(i,j) =max(imag1(I, j)+imag2(I, j))

**Discrete Cosine Transform**

Decompose source images into sub- blocks
Apply 2D-DCT for each sub-block
Calculate normalized transform coefficients
Mean value of 8*8 block of images
Choose the sub-block which has high value of mean
For all these sub-blocks compute 2D-IDCT to get fused image

**Principal Component Analysis**

The PCA is used extensively in image compression and image classification. The PCA involves a mathematical procedure that transforms a number of correlated variables into a number of uncorrelated variables called principal components. It computes a compact and optimal description of the data set. The first principal component accounts for as much of the variance in the data as possible and each succeeding component accounts for as much of the remaining variance as possible. First principal component is taken to be along the direction with the maximum variance. The second principal component is constrained to lie in the subspace perpendicular of the first. Within this Subspace, this component points the direction of maximum variance. The
third principal component is taken in the maximum variance direction in the subspace perpendicular to the first two and so on as depicted in the Fig.2

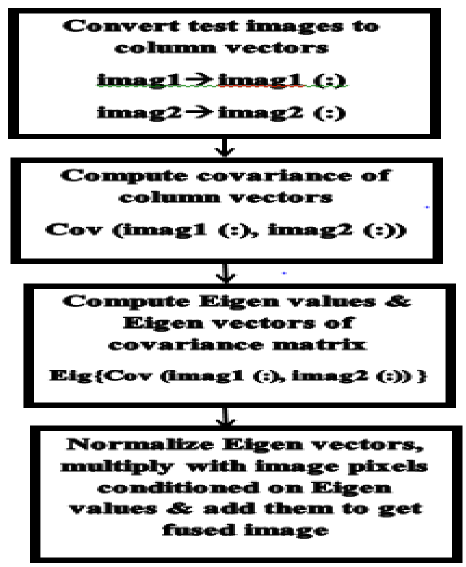


Figure 2. Flow Chart for Image Fusion using PCA

**Wavelet based fusion algorithms**

Wavelets have proven to be good multi resolution analysis tool.
The test images are decomposed into their wavelet co-efficients and then fusion rules are applied as explained in the below algorithm. For example test image1 can be decomposed into approximate and detailed co-efficients as shown in Fig.
Decompose the source images using wavedec2 () which result in three details sub bands and one approximation sub band (HL, LH, HH and LL bands respectively).
Then take the maximum of approximate parts of images.
Take the absolute values of horizontal details of the image and subtract the second part of image from first.
D = (abs (HJLJ)-abs (HJ+1LJ+1))>=0
For fused horizontal part make element wise multiplication of D and horizontal detail of first image and then subtract another horizontal detail of second image multiplied by logical not of D from first.
Find D for vertical and diagonal parts and obtain the fused vertical and details of image.
Fused image is obtained by using waverec2 ().

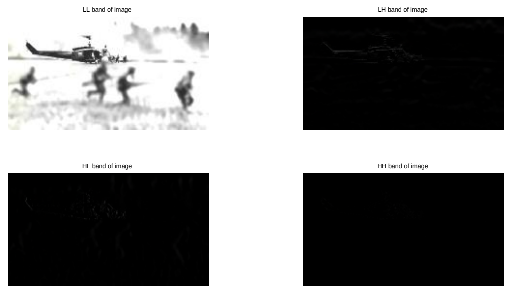


Figure 3. One level decomposition of test image 1

Similar steps can be used to obtain fused image using Stationary Wavelet Transform using swt2 () and iswt2() functions.

## Network Model And Evaluation Parameters

### Network Model

We have considered the simple network model that is shown in Fig. The set of assumptions made are
The source group consists of the fixed set of nodes 1, 2, 3, 4, 5 which are assumed to be camera enabled.
Node1 is assumed to capture the one test image 1 and so on which are shown in Fig.
Ideal channel is exists between the nodes.
Nodes are available to transmit image at any instant of time.

The work at shell can be put in the flow short shown in Fig. It may happen that not all the nodes deployed have sufficient bandwidth to transmit the fused image. Thus we have found the route through the bandwidth constrained nodes as shown in Fig.

Node 1, 2,3,4,5 capture the imag1, image 2, image 3, image 4 and image 5 respectively in which only one feature is prominent. Thus instead of transmitting the images as they are captured to the sink and fusing the images at the sink images are successively fused starting from node 2 which fuses image 1 and image 2. Node 2 transmits fused image to Node 3.Node 3 fuses image 3 and previously received fused image .Finally fused from the Node 5 is routed to the sink.

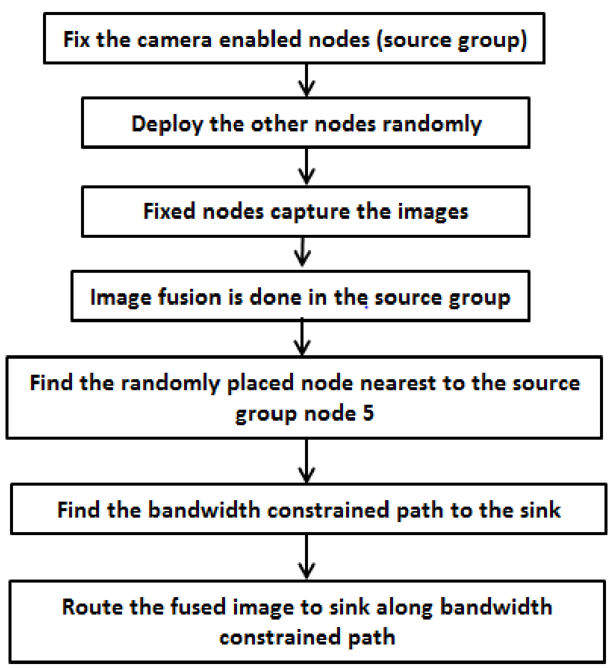


Figure 4. Flow Chart for transmission of fused image along bandwidth constraint route

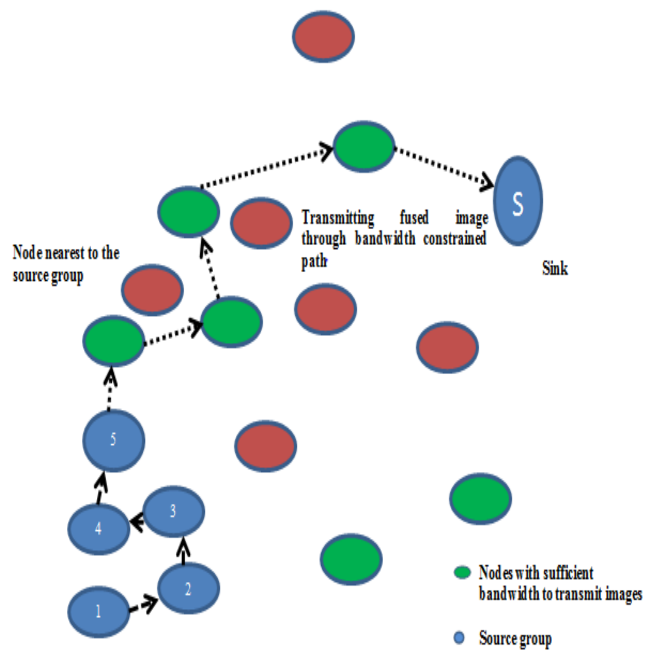


Figure 5. Considered Network topology

**Image Fusion Evaluation Parameters**

The fused image is evaluated in terms of Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Correlation, Signal-to-Noise Ratio (SNR), Mutual Information (MI), and Measure of Structural Similarity (SSIM) as given in [5] with respect to the reference image.

**Network Evaluation Parameters**

WSNs are energy and time constrained. Less the latency and energy consumed more favorable the scheme for improving the lifetime of the network.

End-to-End Delay($D_{EE}$)

In a packet switched network the end-to-end delay is the time taken for a packet to be transmitted across a network from source to destination. This is the time taken by image to reach sink from node. This is given by equation (1).

$$D_{EE}=N_h\,[D_{pg}+D_t+D_{pc}] \quad (1)$$
$$D_p=D/S$$
$$D_t=N/R$$

Where $D_{pg}$ is Propagation delay , $D_t$ is Transmission delay, $D_{pc}$ is Processing delay, D is the distance between nodes, S speed of radio wave in the wireless media, R is the bit rate of the link between the nodes and $N_h$ is number of hops.

In a packet switching network, transmission delay is the amount of time required to push all of the packet's bits into the communication media i.e. the radio in case of WSNs. This is the due to the data-rate of the link. We have considered
250Kbps i.e. for Zigbee compliant network. $D_t$ is a function
of the packet's length and it is proportional to packet's length in bits. $D_t$ is independent of the distance between the two
nodes.

Processing delay is the time it takes routers to process the packet header. Processing delay is a key component in network delay. For simplicity since header is not that much bigger in WSN we are considering this as the time required for image fusion at the node. Different algorithms have different processing time which results in variation in the end-to-end delay.

## Energy Model

A very simple energy model is considered from [10] given by

$$E_{bit\,(TX)} = Ea^* \, d^2 + E_e \qquad (2)$$
$$E_{bit\,(RX)} = E_e$$

Where $E_a$ is energy dissipated in Joules per bit per $m^2$, $E_e$ is energy consumed by the circuit per bit, D is distance b/w TX & RX. These values for mica 2 are $E_a$ = 100E-12 J/bit/ $m^2$, $E_e$ = 40E-9 J/bit.

## Results And Disscussion

Five registered test images considered for successive image fusion is shown are shown in Fig.6. We can observe that only one feature is evident each of the images. Goal of our work is to fuse them successively at the nodes instead of transmitting individual capture images.

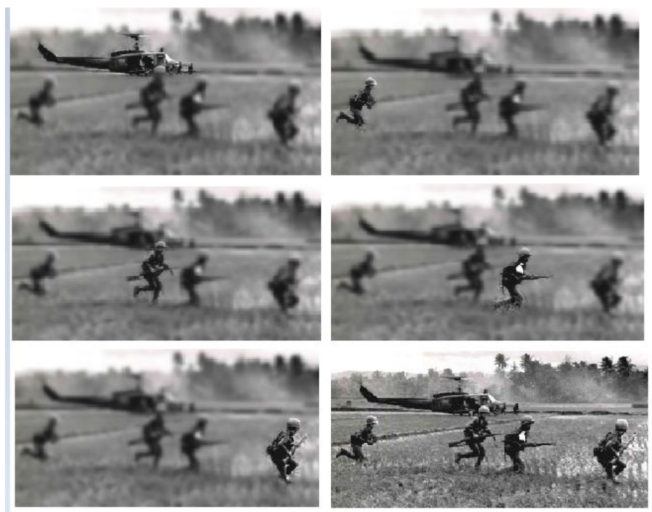

Figure 6. Test images and last image is the reference image taken from www.pythiapress.com

Figure 7. Fused images obtained using averaging, select maximum, PCA, DCT, DWT, SWT respectively (in sequence starting from left most image)

From Fig. 7, Table. I and Fig. 9 we can observe that primitive fusion algorithm averaging gives worst performance. Therefore we can't prefer it even $D_{EE}$ due to it is very minimum. The other primitive algorithm select gives maximum relatively good result in this context. If tradeoff is to favor simplicity, time it is good choice compared to DWT. Though SWT is shift invariant it introduces long delay. Though DCT is widely used in compression technique it is time consuming we can opt for DWT so as to fuse and compress images prior to transmission.

Table 1. Values of image fusion algorithm evaluation parameters for different algorithms

| Par./Alg. | Avg. | Sel. Max | PCA | DCT | DWT | SWT |
|---|---|---|---|---|---|---|
| RMSE | 47.5681 | 18.8074 | 19.9060 | 17.2679 | 16.3526 | 16.2730 |
| MAE | 31.2904 | 13.0479 | 13.9811 | 11.8255 | 11.2495 | 11.1957 |
| CORR | 0.9350 | 0.9916 | 0.9904 | 0.99286 | 0.9936 | 0.9938 |
| SNR | 9.7420 | 17.8018 | 17.3087 | 35.7924 | 19.0166 | 19.0754 |
| MI | 1.0890 | 1.1363 | 1.1363 | 1.1489 | 1.1474 | 1.1480 |
| SSIM | 0.451 | 0.5555 | 0.5193 | 0.5918 | 0.5989 | 0.6047 |
| QI | 0.1586 | 0.3253 | 0.2792 | 0.36606 | 0.3637 | 0.3789 |

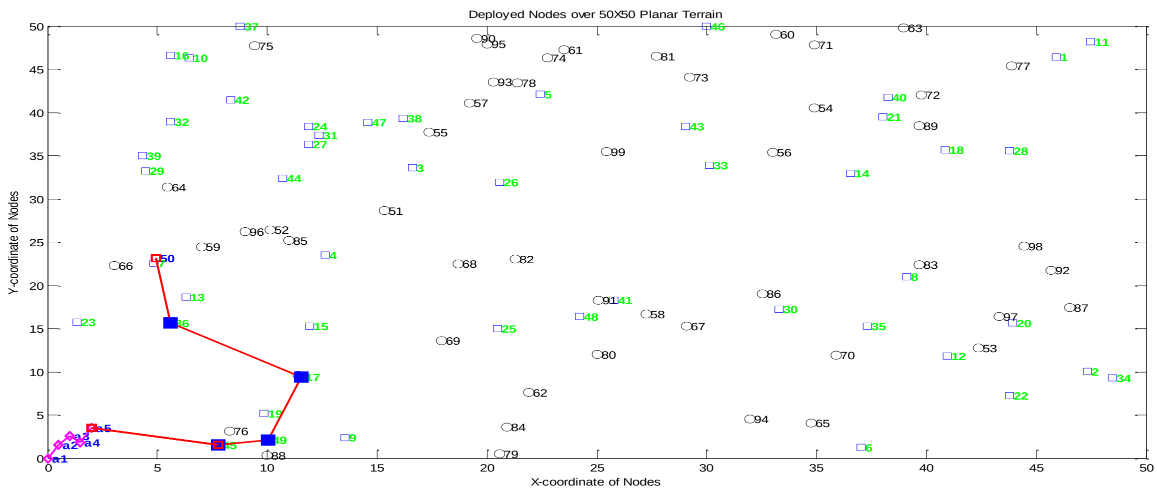


Figure 8. Network topology and the routing path wit 50th node as sink

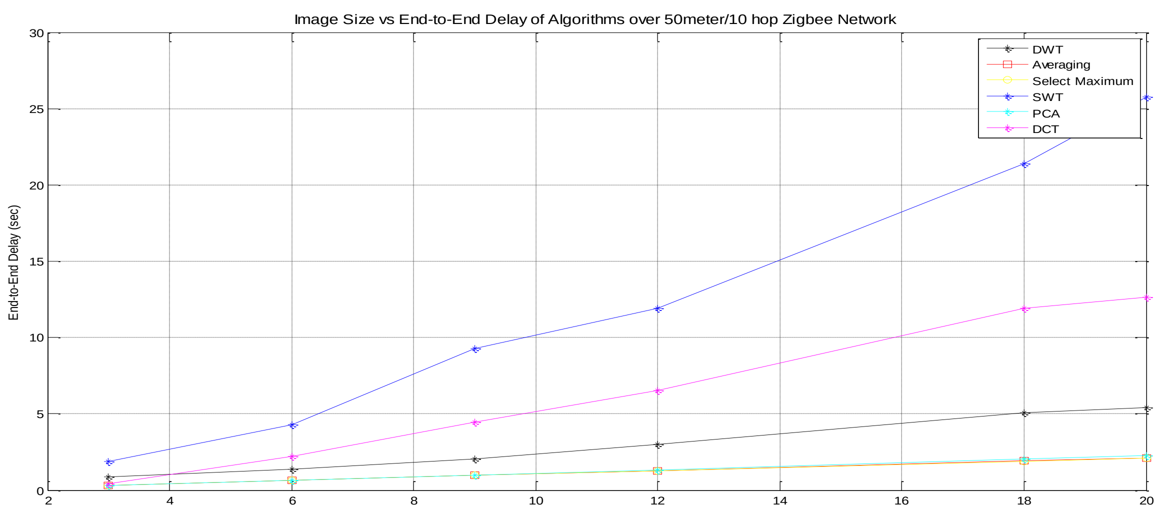


Figure 9. End-to-end delay due to various fusion methods over 50meters/10 hops routing path shown in Fig.8

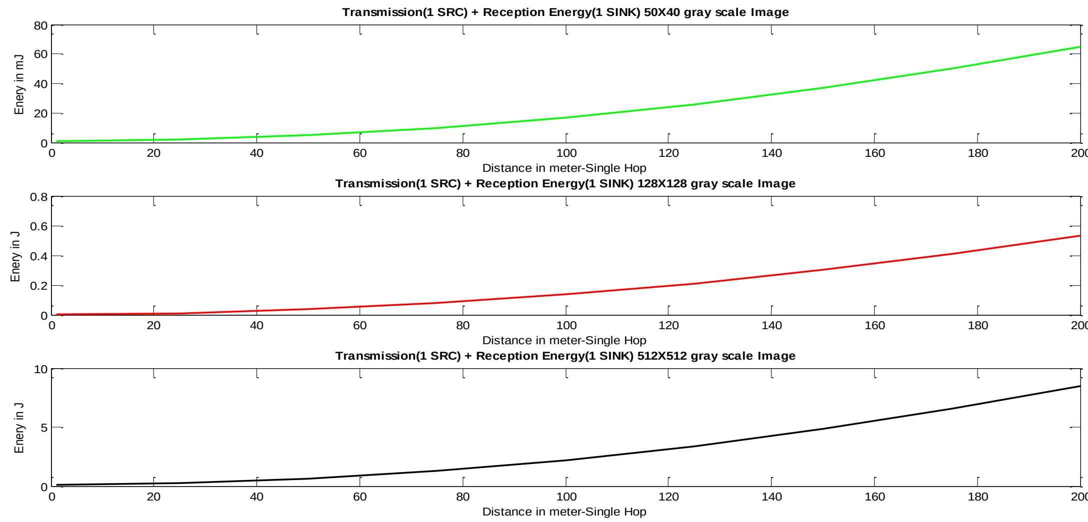


Figure 10. Energy consumption versus distance

## Conclusion

Image fusion has greater prominence in sensor networks as individual sensor based images give little benefits. WMSNs are bound to use image fusion in one or the other context. Though there exist numerous image fusion techniques ranging from simple averaging to contourlet transform, the characteristic properties of WSN limits our options to less computation , less complex and energy efficient algorithms. Wavelets have proven a handy tool for image fusion. But for WSN we need to choose the algorithms based upon the application as they affect the network characteristics.

## Future Work And Scope For Research

Our future aims at implementing the algorithms with much real network model considering the each layer effect in detail.

WMSNs are evolving to yield vast applications. The image fusion techniques available in the field of image processing and analysis having greater complexity and computations have to smartly modify to adopt to exploit image fusion flavor in WSN. Since WMSNs are energy constrained ad-hoc networks energy aware distributive nature of these algorithms along with taking advantage of the compression techniques, error resilient multipath routing would better suit the scenario.

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