A modified QWT for image transmission in WMSN: Study and Experimental

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Summary
The new compression algorithm based on the Modified Quincunx Wavelets Transform and coupled with the progressive encoder SPIHT (MQWT) is considered one of the algorithms are best suited to reduce the size of the data collected by the Multimedia sensor node. The main objective of this article is to introduce our algorithm (MQWT) to low bitrates in a Wireless Multimedia Sensor Network (WMSN), in order to reduce the complexity of the system, as well as the processing time for the use of the memory. The experimental results show the superiority of the proposed algorithm in terms processing time, the transmission time, the energy consumed during the transmission, the throughput (minimize the transmission delay, and a satisfactory throughput for the bandwidth) and compression performance of the reconstructed image in terms of image quality (PSNR).

Key words:
Energy Economy, Image compression, Quality of service, Quincunx wavelets, Wireless Multimedia Sensor Network.

1. Introduction

This work is a contribution to the processing and transmission of images through the networks of multimedia wireless sensors in recital the constraint of the consumption of energy and an underlying, as well as the constraint of quality of service (QoS). This second constraint is essential since the wireless transmissions are fallible (transmission errors due to interference, possibility of collisions and congestion, hardware failure of the nodes of the network, the extinction of the nodes as a result of the depletion of their batteries). The loss of packets can easily be corrected at the level of the protocol of communication by example with a mechanism based on the acquittals and packet retransmissions, but at a cost of energy which must be recognized. The correction of the losses of packets will allow ensuring a minimum terminal of the quality of the final images, but it leads to an increase in the energy consumed by the network and for delays in delivery of packets. Our objective is to propose solutions that provide a compromise between the energy consumed by the sensors and the quality of the received images [1].

The image compression is the optimal solution to solve these problems simultaneously [2-4]. This phase allows you to save a lot of energy, by the sending of a small quantity of the information (image compressed) in the circumstances of excellent quality of the network in terms of the flow of information and without loss of packets in good time, in comparison with the transmission of the original image that consumes more energy in poor network conditions such as the flow of information very great that occupies the bandwidth and abandons a very important number of packets in a significant period of time.

2. Context and related work

The techniques of compression can be classified in two main categories; with and without loss [5]. The choice of the compression technique depends on the operating platform. However, the limited resources such as in the Platform WMSN require compression techniques with less complexity of calculation, lower energy consumption and an acceptable image quality. The techniques of compression with loss are strongly encouraged for WMSN [3, 5, 6].

It is interesting to note that, M. Beladgham and al [7] have proposed an algorithm of the compression of images based medical, on the basis wavelet transform coupled with the SPIHT coding. The results achieved [7] show that the algorithm proposed is better adapted to the compression of medical images.

3. Quincunx Wavelets Transform

The analysis dyadic separable requires three families of Wavelet, this is sometimes considered as a disadvantage, and on the other hand the dilation factor between two successive scales is 4, which may seem high. It is possible to remedy these two problems, but it is at the price of the loss of the separability of the filters and therefore an algorithmic complexity a little higher. An analysis has been particularly studied and has found practical applications; it is the so-called analysis in "staggered ". The Fig. 1 illustrates this type of decomposition [8].

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We will see that the factor of dilation is limited to 2 between two successive resolutions and that a single family of wavelets is necessary [8].

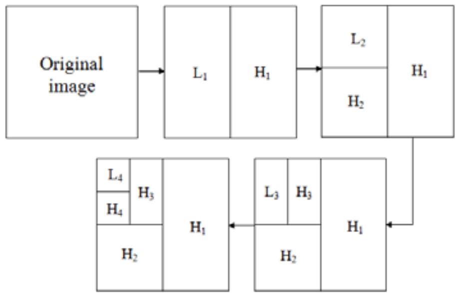
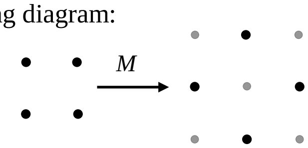


Fig. 1 Decomposition in staggered wavelets (3iterations)

The matrix of dilation in this case will be: $M = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$

The transformation of the mesh (lattice) is done according to the following diagram:



This matrix generates a lattice staggered alignment in dimension 2. The column vectors of this matrix form a basis of this lattice. The volume of the basic cell associated worth 2 (Fig.2). This same lattice is also derived from the matrix [9, 10]: $M' = \begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}$

We note that the no dilatation is $\sqrt{2}$ on each branch and the geometry of the mesh obtained justifies the name given to this analysis multi-resolution [11].

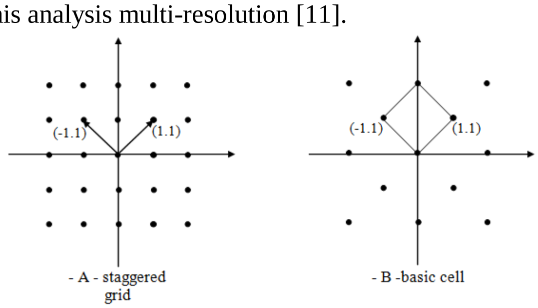


Fig. 2 Example of the quincunx grid and the elementary cell

The simplified version in staggered alignment of $x[\vec{n}]$ is:

$$[x]_{\downarrow M}[\vec{n}] = x[M\vec{n}] \quad with \quad M = \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} \quad (1)$$

We note that $|\det(M)| = 2$, which indicates that the reduction of the size of the image is 2 (non-separable) instead of 4 in the case separable. In the Fourier domain equation 2 is then writes:

$$[x]_{\downarrow M}[\vec{n}] \leftrightarrow \frac{1}{2}\left[X(e^{jM^{-T}\vec{\omega}}) + X(e^{j(M^{-T}\vec{\omega}+\vec{\pi})})\right] \quad (2)$$

With $\vec{\pi} = (\pi, \pi)$.

The on-sampling is defined by

$$[x]_{\uparrow M}[\vec{n}] = \begin{cases} x[M^{-1}\vec{n}], & si\ n_1 + n_2\ is\ pair \\ 0 & elsewhere \end{cases} \quad (3)$$

In the Fourier domain is obtained:

$$[x]_{\uparrow M}[\vec{n}] \longleftrightarrow X(e^{jM^T\vec{\omega}}) \quad (4)$$

According to (2) and (5), be deduced a formula of a sub-sampling followed by a on-sampling described as follows:

$$[x]_{\downarrow M \uparrow M}[\vec{n}] = \begin{cases} x[\vec{n}], & if\ n_1 + n_2\ is\ pair \\ 0 & elsewhere \end{cases} \quad (5)$$

This gives in the Fourier domain:

$$[x]_{\downarrow M \uparrow M}[\vec{n}] = \frac{1}{2}\left[X(e^{j\vec{\omega}}) + X(e^{j(\vec{\omega}+\vec{\pi})})\right] \quad (6)$$

As long as the sampling in staggered alignment reduces the size of the image by a factor of 2, then the bench of filters associated with the two channels is given by the Fig. 3 [12, 13]. The low-pass filter $\tilde{H}$ reduces the resolution by a factor of $\sqrt{2}$. The coefficients of the wavelet correspond to the output of the high-pass filter $\tilde{G}$.

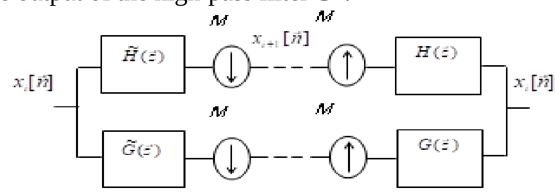


Fig. 3 Example of the staggered grid and the basic cell

The used filters are symmetrical and designed to have zeros of the Order α to $z = -1$; the numerator is a fractional power of $(z + 2 + z^{-1})$ (The simple filter symmetric refinement of order 2). It should also be noted that these filters are at maximum flat to the origin, they behave as essentially $H_\alpha(z)/\sqrt{2} = 1 + O(\omega^\alpha)$. Their frequency response is similar to the filters of the Daubechies with two important differences: 1 (Filters are symmetrical, 2) the order is not limited to integer values [14, 15].

4. Proposed algorithm

In the Iteration horizontal, we have changed the number of descendant when the coefficient is insignificant.

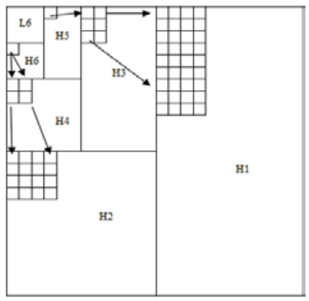


Fig. 4- SPIHT decomposition

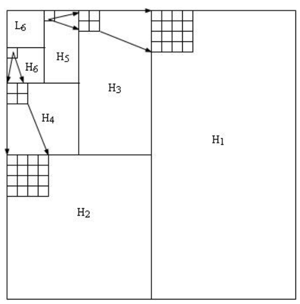


Fig. 5 Decomposition classic SPIHT

Then the decomposition follows the nature of the sub-band of the analysis by transformed.

Example: the coefficient which belongs to H5 is insignificant will decompose in six descendants instead of four. However, in the iterations pairs, the number of descendants remains the same.

The second modification, we removed the block of encoder arithmetic to reduce the complexity of the algorithm.

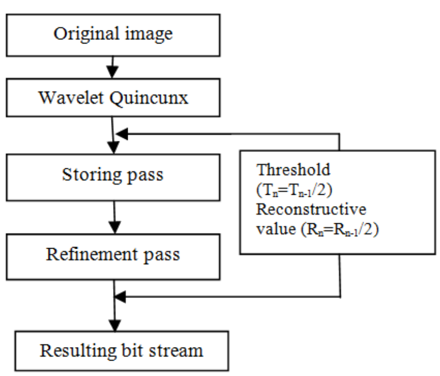


Fig. 6 A MQWT Operational diagram

- ***Compression image performance criteria***

The *compression ratio* (*CR*) as shown in the formula (3); when the compression ratio is higher, energy consumption is less.

$$Cr = \frac{B_o}{B_i} \quad (7)$$

Where, B_o is the output compressed sequence length and B_i is the uncompressed input length.

Objective measurements are based on mathematical criteria for evaluating image quality. The main quality criteria used to measure the performance of optical instruments [16] are:

The mean square error (MSE), the simplest setting of the image quality measure is the MSE. The great value of MSE means that the image quality is poor. The MSE is defined as follows:

$$MSE = \frac{1}{M.N} . \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} \left[I(i,j) - \hat{I}(i,j) \right]^2 \quad (8)$$

With: $I(i,j)$ represents the original image, $\hat{I}(i,j)$ is the degraded image. M and N are the number of rows and columns.

Peak Signal-to-Noise Ratio (PSNR), is defined as:

$$PSNR = 10 \log_{10} \left(\frac{2^R - 1}{MSE} \right)^2 [dB] \quad (9)$$

5. Experimental

The experimental study is carried out on a Raspberry Pi model B (see Table 1). In addition, the USB connector is connected to the USB WIFI module which is used to transfer the output Stream bit between the network nodes (see Figure 7). Our experiments are carried out on Raspberry Pi.

The implementation of the compression algorithm is carried out in the Raspberry Pi card using the "Octave" software used under the Matlab environment.

NB: Matlab is very fast almost five times compared to Octave [17].

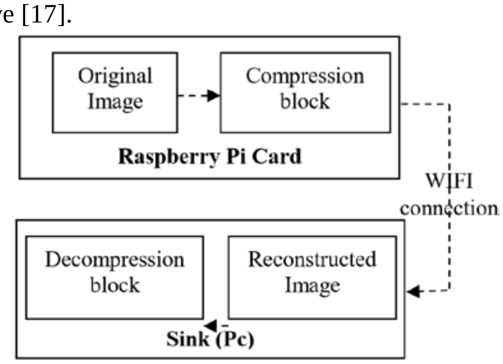


Fig. 7 Architecture of the image transmission system

Table 1: Technical characteristics

Raspberry pi model B	
CPU	Quad Core Broadcom BCM2837
RAM	1 GB
SD card	16 GB
WIFI key	TP link 150 Mb/s
Others: 4 USB ports, HDMI, Power Source: Micro USB, TV Toshiba 32 ".	

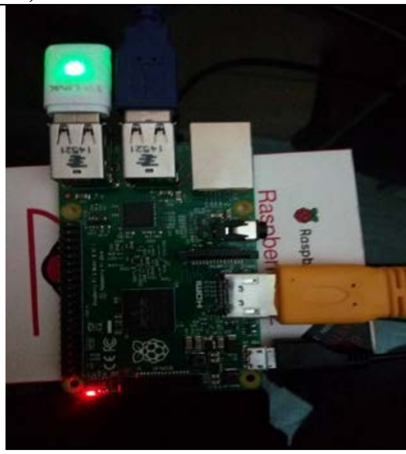


Fig. 8 Raspberry Pi model B

5.1. Steps to Implement the System

Implementation of a system can be defined in the following steps:

- Installing the raspbian system on the memory card;
- Octave installation;
- Running the compression method in the octave environment that gives a ".dat" file that is the result of compression;
- Transmission of the ".dat" file from the Raspberry Pi card to the PC via wifi with the "SSH" protocol. We used the 64 Kb / s bandwidth at a distance (D ≈ 15 m).

5.2. Energy consumption

To calculate the energy consumed during transmission, we performed several tests to find the following values: I = 5 V and U≈440 mA, we used the following formulas:

Energy (Joule) = power (Watt) x time (second)

$W = P.t$ (10)

Power = Voltage (Volt) x Current (Ampere)

$P = I.U$ (11)

5.3. Results and discussion

In this section we will apply our MQWT algorithm to compress the Lena and Baboon grayscale images of size 256 * 256 pixels into the raspberry pi card and transmit the compression result to the PC (Sink) via a Wi-Fi connection. The evaluation of the MQWT method compared to other methods (CDF9 / 7 (Filter bank) + SPIHT) based on the following criteria: processing time, throughput, transmission time, energy consumed during the transmission. Finally, the estimation and the judgment of the compressed image quality are given by the PSNR evaluation criterion.

Table 2: Processing Time (s) for Grayscale Lena Image 256 * 256

Bitrate (bpp)	Processing Time (s)	
	CDF9/7(filter bank) +SPIHT	modified QWT
0.125	8	6
0.250	12	11
0.500	21	20
0.750	28	27
1.000	37	34

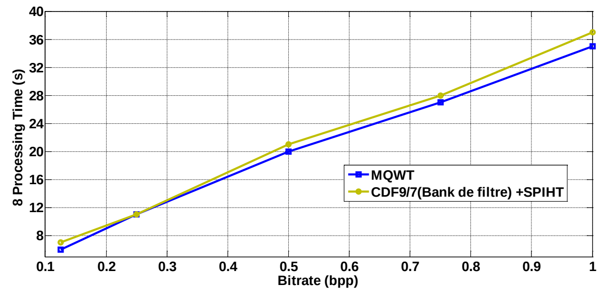


Fig. 9 Processing Time (s) for Grayscale Baboon Image 256 * 256

Table 2 and Fig. 8 illustrate a reduction in the processing time of the MQWT algorithm with respect to the CDF9 / 7 (Filter Bank) + SPIHT algorithm.

On average, the proposed algorithm offers almost 7.54% reduction of time compared to CDF9 / 7 (Filter Bank) + SPIHT. Admittedly, the reduction in processing time reduces the complexity of the system and consequently the energy consumption.

The transmission is implemented at a distance D ≈ 15 meters with a bandwidth of 64 Kb/s.

Table 3: Transmission time (s) for (D ≈ 15 m)

Bitrate (bpp)	Transmission time (s) for (D ≈ 15 m)
0.125	4
0.250	11
0.500	16
0.750	22
1.000	26

Table 4: Energy consumed during transmission (Joule) for (D ≈ 15 m)

Bitrate (bpp)	Energy consumed during transmission (Joule) for (D ≈ 15 m)
0.125	≈ 8,8
0.250	≈ 24,2
0.500	≈ 35,2
0.750	≈ 48,4
1.000	≈ 57,2

Table 3 and 4 show the transmission time and the energy consumption of a compressed image as a function of different bitrates in a distance (D ≈ 15 m). We note that there is a relation between time and distance Energy consumed. Reduced transmission time reduces energy consumption.

Table 5: Transmission speed (b / s) for (D ≈ 15 m)

Bitrate (bpp)	Transmission speed (b / s) for (D ≈ 15 m)
0.125	33 351
0.250	56 462
0.500	60 961
0.750	64 293
1.000	65 388

Table 5 presents the transmission speed (b / s) for (D ≈ 15 m) of a compressed image of different bitrates in a 64 Kb / s bandwidth (65536 b / s). We notice that the bitrate is varied (increase) in a bit rate increase, knowing that the very large volume of information occupies the bandwidth and giving up a very large number of packets in a very big time.

Table 6: Comparison of PSNR results (dB) between algorithm MQWT and CDF9 / 7 (Filter Bank) + SPIHT, for grayscale image Lena 256 * 256

Bitrate (bpp)	PSNR (dB) pour l'image niveau de gris Lena 256 * 256	
	CDF9/7(filter bank) +SPIHT	modified QWT
0.125	21.69	24.56
0.250	25.44	27.65
0.500	29.70	31.27
0.750	31.89	33.80
1.000	35.71	36.29

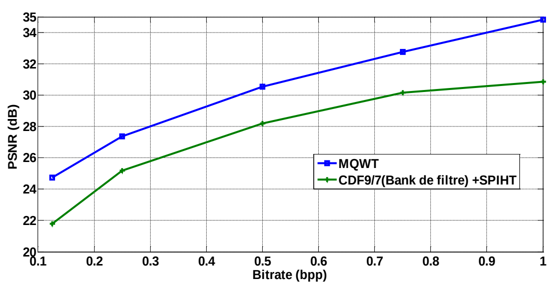


Fig. 9 Comparison of the PSNR results (dB) between the algorithm MQWT and CDF9 / 7 (Filter Bank) + SPIHT, for the gray level image Baboon256 * 256

Table 6 and Fig. 9 shown below show the quality of the compressed image for different values of the bitrates (number of bits per pixel). According to the PSNR values, we notice that from 0.25bpp the reconstruction of the image becomes quasi-perfect, and they clearly show the effectiveness of our proposed algorithm (MQWT) Compressed image for low bitrates.

6. Conclusion

In this paper, we realized a transmission system based on the Raspberry Pi card using the adapted software (raspbian system and the octave environment).
We implemented our compression algorithms (MQWT and CDF9 / 7 (Filter Bank) + SPIHT) in this system.
We evaluated this transmission chain by the following criteria: compression time, throughput, transmission time, energy consumed during transmission, and estimation and judgment of image quality is given by the PSNR.
The results show the superiority of the proposed compression algorithm at low Bitrates in terms of complexity of the system as well as processing time, transmission time, power consumed during transmission, throughput (minimize delay of the transmission, with a satisfactory throughput for the bandwidth) and the compression performance of the reconstructed image.
In perspective, we wanted to introduce the video sequences into our transmission system. On the other hand, the use of powerful cards for our system will be possible.

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Khelifa Benahmed has done his research for Ph.D. degree in the field of sensor networks wireless at the school of computing and mathematical sciences at Liverpool john moores university, UK. He has 26 years of experience in education and research at the University Tahri Mohamed Bechar, Algeria. Khelifa has also several international publications in the fields: wireless sensor networks, security, surveillance, smart grid, Internet of things, and smart irrigation. Khelifa holds Engineer, Magister degrees and PhD in Computer sciences in University of Oran Algeria.

Mohammed BELADGHAM was born in Tlemcen, Algeria. He received the dipl. El.-Ing.from the university of Tlemcen, Algeria, and then a Master in signals and systems from the university of Tlemcen, Algeria. Since December 2012, he graduated PhD Es Sciences at the University of Tlemcen. His research interests are Image processing, Medical image compression, wavelets transform and optimal encoder.

When I was appointed as a lecturer in Calais in 1992, I wanted to pursue my research work started in the framework of my doctoral thesis which dealt with the processing of images for extraction and learning of data.

During his years of research I had a PhD thesis in 1998 on the segmentation of images using the Hough transform and its acceleration. This thesis allowed the candidate initially Prag to become in 1999 master of conference in Calais. Then a second thesis, for which I found a co-financing between the regional council of north pas de calais and the institute Calot de Berck. This thesis proposed solutions for the analysis of deformities of the lumbar spine using active contours and data fusion. It was supported in 2001 and the candidate although qualified for the 61st section has preferred to go towards the industry, since 2002 he has been employed as a project manager.

I then devoted my time to valuing my research in the form of articles in international journals. At the same time, I wrote my HDR dissertation, which I supported in December 2003. I also applied at the same time to the list of qualifications I received in February 2004. I Was appointed Pr at the IUT of Valenciennes in September 2004, since I carry out my research in the laboratory LAMIH Valenciennes.

Throughout these years, I have imposed that the candidates, whom I directed or co-directed as part of their thesis, must imperatively have at least in their cv an international conferences with deeds and a publication in a International journal with impact factor to enhance their thesis work of the student but also of the host laboratory.

Since then, my integration with the Lamih, I continue to work in the field of image processing but also signal. I have since 2004 so far supported 4 theses.