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Multi-orientation Property of Gabor Wavelet in Astronomical Images Compressed

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Abstract

In the present paper, Gabor wavelet bases properties are studied. A novel and effective method for Multi-orientation property of Gabor wavelet in astronomical image compression is introduced. A comparative different Gabor wavelet bases is discussed. analysis of orientation invariant feature extraction using

The main advantage of the Gabor wavelet transform are the multi-resolution analysis and multi-orientation property. Multi-orientation of Gabor bases function used to increase the resolution of compressed image in this paper, each orientation has level reflects characteristics of the image at a various directions and spatial resolution. Hence, it can analyze textures of image and detect edges of its with describe them at these orientations and resolutions. For this maters the Gabor wavelet transform concedered a best optimizations for image transformations.

Experimental results show that, whenever the angles increased for Gabor wavelets analysis, the astronomical compressed images have more accuracy and outperform better than the loss of angles orientation.

Keyword: Gabor wavelet , milt-orientation, milt-resolution, compression, JPEG2000.

1.Introduction

Mathematical transforms are important tools in applied mathematics, engineering, physics, and computer science. There are several different transformations such as Fourier Transform (FT), Discrete Cosine Transform (DCT), and Wavelet Transform

(WT). The aim of these transforms is to transform the mathematical functions that depende on time variable to functions depende on frequency variable [1].

Fourier transform has been the most commonly used mathematical tool for analyzing frequency properties of a given

signal, while after transformation, the information about time is lost and it's hard

to tell where a certain frequency occurs. To solve this problem, we use a type of Fourier transform technique called *Gabor transform* which is a mathematical transformation firstly proposed by Dennis Gabor in 1946 [2].

From year to year, the quantity of astronomical data increases at an ever growing rate. Today many astronomical images are made from data sets that either are outside the optical window or do not match the characteristics of the human eye. A hypothesis of how the data are correlated is given by the choice of the transform. The more accurate this assumption is, then the more faithfully the chosen transform will represent the data and decrease the entropy.

The wavelet transform (WT) is considered one of the best tools to do this job. It allows separating the components of an image according to their size. It is also useful for detection of the different components contained in the image. For instance, it has been shown that an image can be completely (or almost completely) reconstructed from its multi scale edges [3].

Gabor wavelet transform makes it possible to analyze a signal $f(x)$ in time and in frequency simultaneously, the idea is to

make a Fourier transform inside a window that will be translated along the signal. Gabor wavelets allow local frequency information to be extracted from an image. The Gabor wavelets are recognized to be good feature detectors [4], in which they estimate the strength of certain frequency bands and orientations at each location in the image, giving a result in the spatial domain.

In computer science, Gabor wavelet transformation supplied to solve many application problems such as, a problems of image compression, filter design and edge detection [4][5] . Multi-orientation property of Gabor wavelet provide the optimal resolution in both the time and frequency domains, and the Gabor wavelet seems to be the optimal basis functions to extract local features such as discontinuity feature from image by using its important properties [6].

The paper is organized as follows; Section 2 deals with Gabor wavelet, section3 explain the stages of JPEG2000 algorithm and its optimization by using Gabor wavelet and quantization, in section 4 the proposed method with results is introduced and the conclusion of this study is given in section 5.

2. Gabor Wavelet (GW)

For analyze the signals (functions) with different frequency components, Gabor wavelet transform is developed. This transform uses Gabor wavelets such a basis functions to create an expansion of a non-stationary signal $f(x)$ in terms of time-frequency atoms. This wavelet constructed by a window function $g_{\tau,\omega}(x)$ (which is a Gaussian function represented by Eq.(1) , combined to a complex exponential [7].

The design of Gaussian function is given in the form [6]: $g(x,y)=\frac{\|\vec{k_i}\|^2}{\sigma_x\sigma_y}e^{-\frac{\|\vec{k_i}\|^2}{2}(\frac{x^2}{\sigma_x{}^2}+\frac{y^2}{\sigma_y{}^2})}$ …(1)

The Gabor wavelet in 2-D is expressed as[6][7]:

GW= $\psi_i(x,y)=\frac{\|\vec{k_i}\|^2}{\sigma_x\sigma_y}e^{-\frac{\|\vec{k_i}\|^2}{2}(\frac{x^2}{\sigma_x{}^2}+\frac{y^2}{\sigma_y{}^2})}\left[e^{jk_v(x\cos\alpha_\mu+y\sin\alpha_\mu)}-e^{\frac{-\sigma_x\sigma_y}{2}}\right]$

…(2)

Where $x=-(R/2),...,(R/2)$,

and $y=-(C/2),...,(C/2)$, such that, R and C=128.

Each $\psi_i(x,y)$ is a plane wave characterized by the vector k_i enveloped by a Gaussian function, where σ_x,σ_y is the standard deviation of this Gaussian along x and y-axis. The center frequency of ith window is given by the characteristic wave vector,

where wave vector equation is

…(3) $\vec{k_i}=\begin{pmatrix}k_{ix}\\k_{iy}\end{pmatrix}=\begin{pmatrix}k_v\cos\alpha_u\\k_v\sin\alpha_u\end{pmatrix}$

Having a scale and orientation given by (k_v,α_u)

where

$k_v=2^{-\frac{v+2}{2}}\pi$ …(4)

$\alpha_u=u\frac{\pi}{U}$ …(5)

Where $v=0,1,...V-1$ and $u=0,1,...U-1$;

V,U are a max number of scaling and rotation factor respectively, where u, v are the direction and scale of Gabor wavelets, respectively,(x,y) is the coordinate of a pixel in image. An extra parameter α_u provides selectivity for the orientation of the function[7]. The $\psi(x,y)$ of Eq.(2) can be used as the mother wavelet to decompose a signal into various levels and orientations. In this section, we showed how mother wavelets could be used in the design of discrete wavelet transform . The same procedure can be applied to the mother Gabor wavelet, which will be applied in the application of this paper.

2.1 Important Properties of Gabor Wavelet.

1. Multi-orientation property.
2. Multi-resolution property.
3. Bi-orthogonal.
4. Continuity.
5. Separability.

In the following section we are going to give a break description of the well-known jpeg2000 algorithm and explain our modification on this algorithm using Gabor wavelet to optimizing for compression astronomical image purposes.

3.The Optimization Of JPEG 2000

Algorithm By Gabor Properties

JPEG 2000 is a new standard of image compression ,it is devised with the aim of providing the best quality or performance and capabilities to market evolution that the current JPEG standard fails to supply for.

This compression system model consists of two parts, the compressor and the decompression. The compressor method depended on three fundamental stages are transformation, quantization and coding which they are illustrate in figure (1) . the first stage explain the using of DWT to transform the data from time domain to mathematical space, to optimize JPEG2000 algorithm we used Gabor wavelet. Wavelet compression technique uses the wavelet filters for image decomposition, image is divided into approximation and detail sub image. The decomposition operation of image f(x,y) is represented in the following equations as[6]

$$f(x,y)=\frac{1}{\sqrt{MN}}\sum_{m}\sum_{n}W_{\phi}(s_0,m,n)\phi_{s_0,m,n}(x,y)+\frac{1}{\sqrt{MN}}\sum_{i=H,V,D}\sum_{s=s_0}^{\infty}\sum_{m}\sum_{n}W_{\psi}^{i}(s,m,n)\psi^{i}_{s,m,n}(x,y) \quad ...(6)$$

$$W_{\psi}(s,m,n)=\frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)\psi^{i}{}_{s,m,n}(x,y) \quad ...(7)$$

Where the scaling basis functions and the wavelet basis function from Gabor wavelet are explained in the following, respectively as

$$\phi_{s,m,n}(x,y)=2^{-s/2}\phi(2^{-s}x-m,2^{-s}y-n)$$

…(8)

$$\psi^{i}{}_{s,m,n}(x,y)=2^{-s/2}\psi^{i}(2^{-s}x-m,2^{-s}y-n)$$

…(9)

$for......s > s_0$, and $i = \{H, V, D\}$. Where i ={H,V,D}, as in the one – dimensional case, s_0 is an arbitrary starting scale and the $W_\phi(s_0, m, n)$ coefficients define an approximation of *f (x, y)* at scale s_0 . The $W_\psi^i(s, m, n)$ coefficients add horizontal, vertical, and diagonal details for scales $s \geq s_0$.[We normally let s_0 =0 and select N = M = 2^s so that s = 0,1,2,.......,S -1 and m=n= 0,1,2,......,2^S-1.This operation involves two filters, one is corresponding to the scaling filter or lowpass filter, and the other is corresponding to wavelet filter or high pass filter. Moreover, it is noticed that low-pass filter leads to the scaling function and the high-pass filter leads to wavelet function [8]], By depend on scaling and orientation parameters of Gabor wavelet, each level reflects characteristics of the image at a various directions and spatial resolution . Hence, it can analyze textures of image and detect edges of its with describe them at these orientations and resolutions. For these maters the Gabor wavelet transform considered best optimizations for image transformations.

The output coefficients from the stage one be quantized by using threshold. It's the second stage. In this paper this threshold is obtained by the examined of the sub-band coefficients and get out the variance to them, this value used as a threshold, each wavelet coefficient in the subband is divided by the threshold and the result is truncated. Each subband can have a different quantization step size [9][10]. The quantization step size may be determined iteratively in order to achieve a goal bitrate (i.e., the compression factor may be specified in advance by the user) or in order to achieve a predetermined level of image quality.

In the third stage, we can be coded the quantization coefficients by means of Huffman coding method[1] .

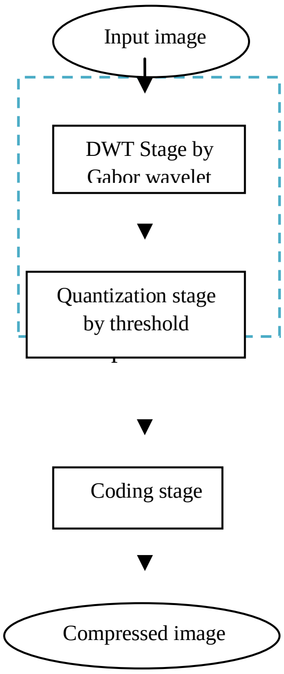


Fig (1):The Compression System Stages

4. Experimental Results

In this section, a detailed experimental comparison of the above stated algorithm has been presented. We have used gray image databases. Figure (2) shows sample data base for astronomical images ,which are used in this paper.

Origin image 1	Gray image 1	Decompressed 1

Image5

Image6

Image7 Image8

Fig(2) : **Sample Data Base for Astronomical Graphic Images**

Results of only four of above images are given by using the results of compression system (CS), the images are (image 1, image 2, image 3, image 4) from the Fig (2). The Table (1) explain the results of this system which illustrate in Fig.3,4,5,6. This results explained and examined by using some of mathematical process such as compression ratio(CR) and peak signal to noise ratio(PSNR). The equations of them are[11][9]:

Compression ratio (CR)= $(1-(\frac{Compressed-size}{Orginal-size}))\times 100$ …(10)

$$\text{PSNR} = 10\log_{10}\frac{(L-1)^2}{\frac{1}{N^2}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}[f(x,y)-f^*(x,y)]^2} \quad \ldots(11)$$

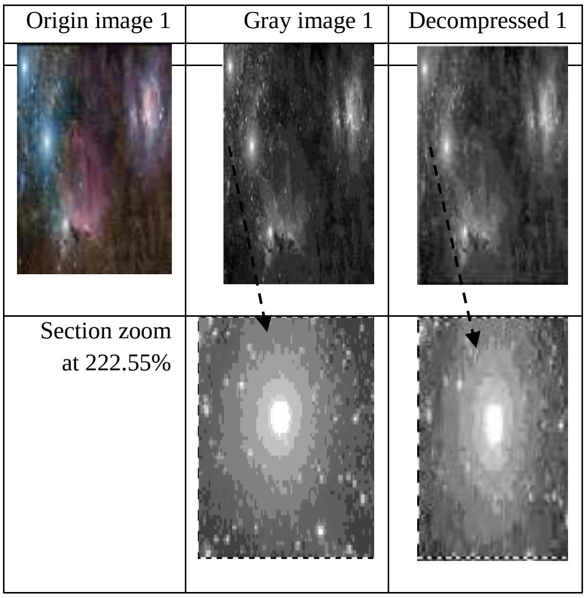
where L is the number of gray levels(e.g., for 8 bits L=256).

$f(x,y)$: the original image, $f^*(x,y)$: the decompressed image, x , y : row and column .

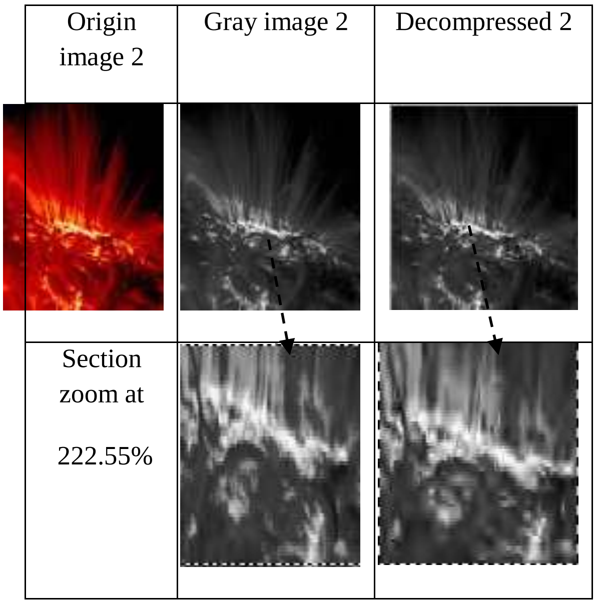
From the experiments results, which they illustrated in table (1), the compression system get high compression ratio, which greater than eighty ,and we can show that the compression images have high resolution by PSNR values, all PSNR values greater than thirty. Actively, Gabor wavelet property assisted this system to get this resultant.

Table (1): The Result of JPEG2000 Algorithm with Gabor Wavelet for (eight) Orientations and (five) Scaling Parameters.

Image No.	Dim	Origin size(kb)	Compressed size(kb)	CR	PSNR
1	512×512	254	37.5	85%	34
2	256×256	192.1	24.1	87%	33
3	512×512	256	22	91.4 %	32
4	512×512	256	21	91.7 %	32



Fig(3): The Decompressed Image1 of The System for(eight) Orientations and (five) Scaling Parameters.



Fig(4): The Decompressed Image2 of The System for (eight) Orientations and (five)Scaling Parameters.

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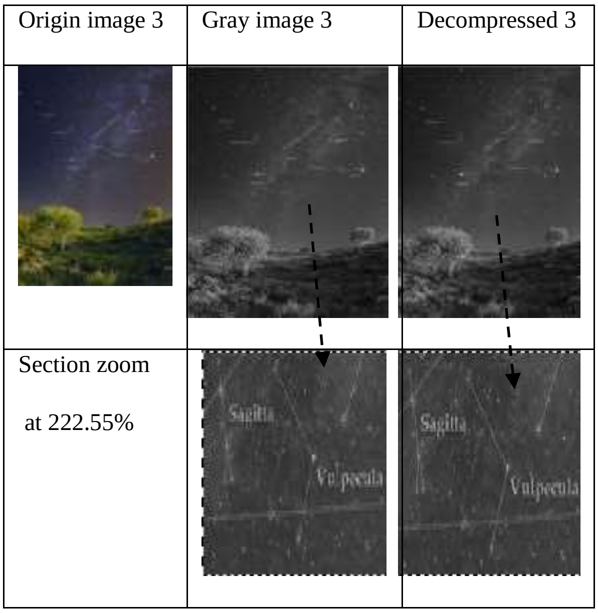
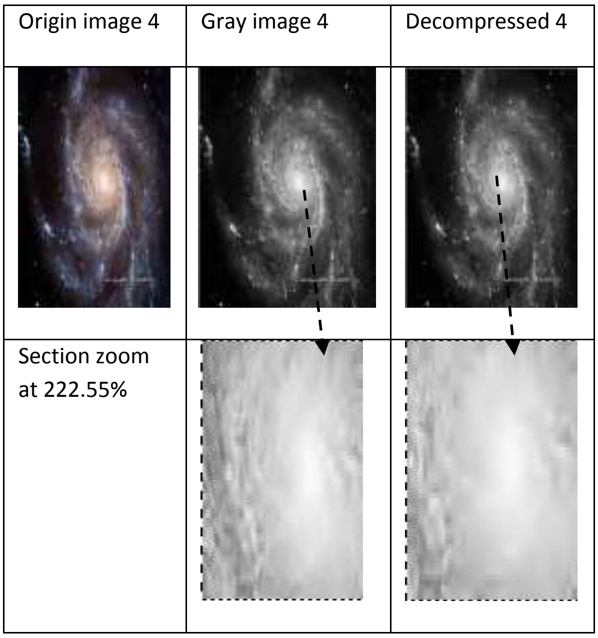


Fig(5): The Decompressed Image3 of The System for (eight) Orientations and (five)Scaling Parameters.

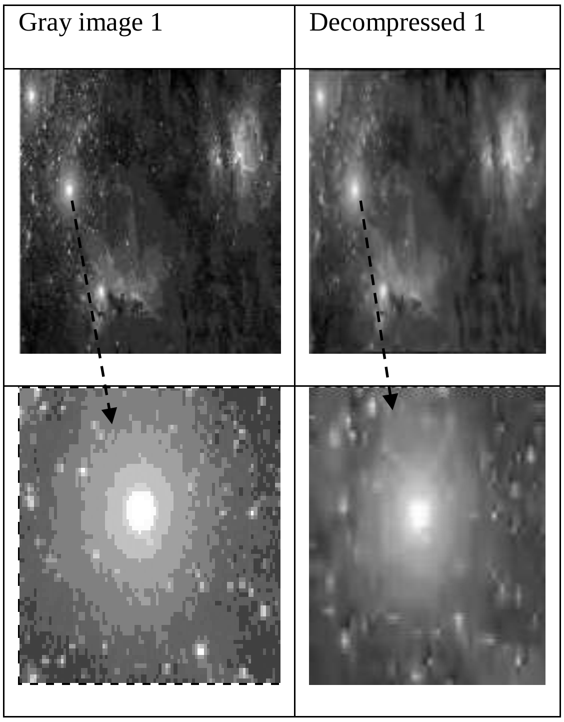


Fig(6): The Decompressed Image4 of The System for (eight) Orientations and (five) Scaling Parameters.

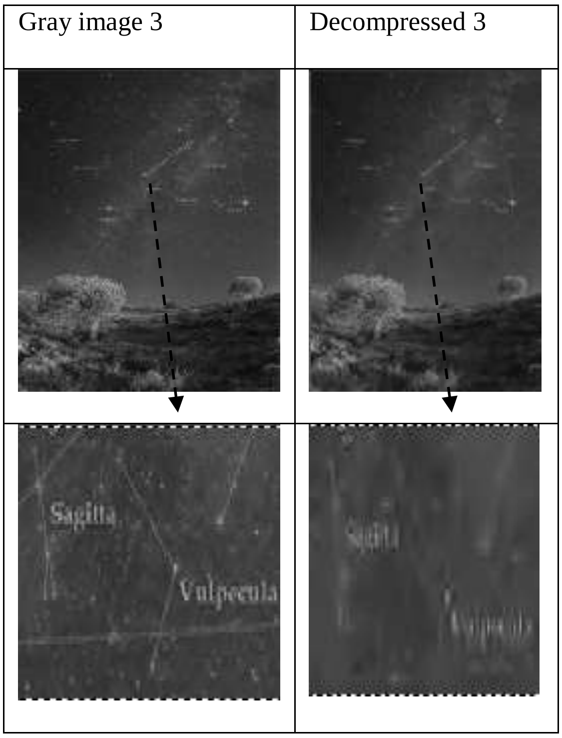
It's very nice to compare the system performance with JPEG-2000 algorithm with Gabor wavelet but for less angles orientations, the results of an images are summarized in Table(2) and the testing images shown in Figure(7,8).

Table (2): The Result of JPEG2000 Algorithm with Gabor Wavelet for (six) Orientations and (five) Scaling Parameters.

Image No.	Origin size (kb)	Compression size (kb)	CR	PSNR
1	254	28	88%	29
3	256	12	95%	28



Fig(7): The Decompressed Image1 of The System for (six) Orientations and (five) Scaling Parameters



Fig(8): The Decompression Image3 of The System for (six) angles Orientations and (five) Scaling Parameters.

5. Conclusion

From the experimental results obtained from the compression system (CS) using different images ,we conclude:

1. The CS give high compression ratios with higher qualities (resolution), all these ratios and qualities be suitable with respect to the *image applications* ,all these are shown in table1.
2. *Multi-orientation* and *multi-resolution* of Gabor wavelet gives the compression system more *activity* and *accuracy* than another wavelet with respect to the another studies, because these properties used to analyze an image and give more accuracy detection for *image features* especially for the *discontinuity (edges) regions*,all these results are shown in fig.3,4,5,6.
3. Increased of an angles number of Gabor wavelet used to increase the PSNR values, this is shown in table1,2.

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الخلاصة

في هذا البحث تطرقنا لدراست الخواص الرياضية لمويجة كابور، ان استخدام خاصية تعدد الاتجاه لدوال القاعدة المكون لمويجة الكابور كان له تاثير كبير في تحسين عملية ضغط الصور باستخدام طريقة الضغط جي بي جي 2000 وبالخصوص في ضغط الصور الفلكية،تم مقارنة ودراسة دور تعدد زوايا الاتجاه مويجة الكابور في تحليل الاشارة(الصورة) الى معاملات المركبات المكونة لها وتاثيرها على استخراج الخصائص والتفاصيل الدقيقة المكونة للصورة.

الميزات المهمة بتحويل مويجة كابور هو تعدد مستويات التحليل وتعدد اتجاهات التحليل ،حيث ان تعدد زوايا الاتجاه التي تتحرك بها دوال القاعدة المكونة لمويجة الكابور تعطي هذا التحليل اكثر كفاءة وتدعم نظام الضغط لاسترجاع صورة مضغوط عالية الجودة وزيادة وضوح الصورة المسترجعة عند كل زيادة في عدد الزوايا ،وبالتالي استخدمت هذه الخاصية لزيادة تحليل الخصائص الدقيقة وتحديد مناطق الحواف الموجودة بالصورة.

التجارب العملية في البحث اثبتت كلما زادت زوايا التدوير للموجة المحللة حصلنا على نسب ضغط عالية ودقة اعلى للصورة المسترجعة مما عليه فيما لو قللنا عدد الزوايا المستخدمة.