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Gabor Wavelet Based Edge detection on Hexagonal sampled Grid

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Abstract

Image processing in hexagonal grid is very much advantageous than in the conventional rectangular grid. The primary motivation behind using a hexagonal pixel grid model is that retina of the eye closely resembles a hexagonal grid space. Thus by modeling and processing images on such a grid space, one can mimic natural behavior to realize Computer Vision. Edge detection is one of the important preprocessing steps in many of the image processing applications. Wavelet based edge detection is found to be a better technique for various applications. In this paper directional Gabor Wavelet based edge detection is performed on hexagonal domain. For performance evaluation peak signal to noise ratio and mean square error is considered. Edge detection on hexagonal domain gives better results and better visual appeal of images compared to edge detection on rectangular domain.

Keywords

Gabor filter, hexagonal sampled grid, image resampling

I. Introduction

The advantages of hexagonal image processing [1] are higher angular resolution, consistent connectivity, higher sampling efficiency, smaller quantization error, equidistance and higher Symmetry. Hexagonal grid approaches has so far not yet been widely used in computer vision and graphics field. The main problem that limits the use of hexagonal image structure is believed due to lack of hardware for capturing and displaying hexagonal-based images. Conversion has to be done from square to hexagonal image before hexagonal-based image processing. Resampling is the process of transforming a discrete image which is defined at one set of coordinate locations to a new set of coordinate points i.e., converting from rectangular to hexagonal grid.

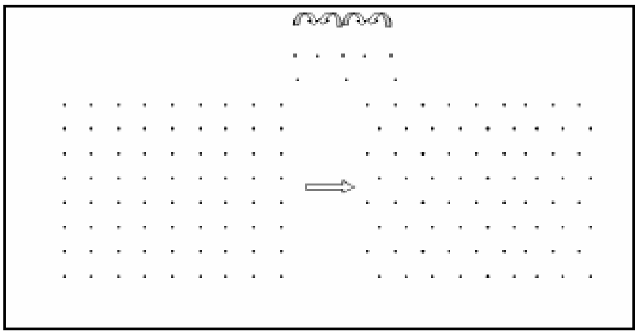
Edge detection is one of the important preprocessing steps in many of the image processing applications. In hexagonal domain the edge detection operations were performed on the hexagonally sampled image. With the growth of wavelet theory, the wavelet transform have been found to be remarkable mathematical tool to analyze the singularities including the edges [2], and further to detect them effectively. The wavelet transform characterizes the local regularity of signals by decomposing signals into elementary building blocks that are well localized both in space and frequency. This not only explains the underlying mechanism of classical edge detectors, but also indicates a way of constructing optimal edge detectors under specific working conditions. Gabor filter [3] is the only filter with orientation selectivity that can be expressed as a sum of only two separable filters. It choose higher frequency information hence the edge is maximized. For rectangular domain we have to select four different orientations to obtain the edges, along 0, 90,270 and 360 degrees. But in Hexagonal domain three degree orientations give better edges along 0, 60,120 degree.

The paper is organized as follows. Section II deals with edge detection using Gabor wavelets on hexagonal sampling grid. Section III deals with performance evaluation and along with comparative study are performed with rectangular sampled grid .Section IV results and discussion and section V deals with conclusion.

II.Hexagonal resampling and edge detection

A. Hexagonal resampling

This paper considers hexagonal grid based on half-pixel shift method [4]. For each odd line, find the midpoint between two adjacent pixels by simple linear interpolation (i.e., mid = ((left + right)/ 2). Discard the left and right, keeping only the mid values. This gives us a hexagonal mapping from a regular square or rectangular grid [5].



(a) (b)

Fig. 1: (a) Rectangular lattice (b) Hexagonal lattice using half-pixel shift method.

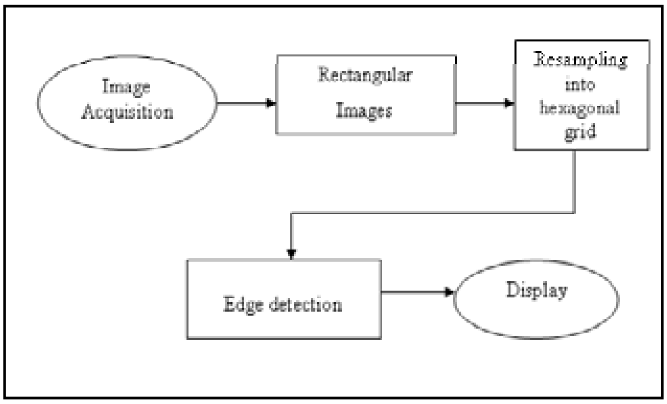


Fig. 2: Functional block diagram of edge detection on hexagonal sampled grid

Sampling on a hexagonal lattice is a promising solution which has been proved to have better efficiency and less aliasing. Its computational power for intelligent vision pushes forward the image processing field. The mean sampling density in the spatial domain is less for hexagonal sampling [6]; hexagonal sampling involves 13.4% fewer samples than rectangular sampling.

B. Gabor Wavelet Based Edge detection

The Gabor filter is basically a Gaussian with variances along x and y-axes, modulated by a complex sinusoid with centre frequencies U and V along x and y-axes respectively. Gabor expansion is a time-frequency analysis method, which was introduced in 1946 by Dennis Gabor [7]. This expansion introduces a time-localization Gaussian window function for extracting local information of signal with the form similar to the Fourier transformation. The Gabor filter tries to search and investigate the intermediate representations which combine the information of both time/space information f and frequency information F. The goal is a simultaneous description of the temporal and spectral behavior of a function or signal f. Such a representation is essentially two dimensional, measuring both behavior of the frequency w and time/space.

Gabor is the only filter which is having the property of directionality. Due to the 3 different axis of symmetry of hexagonal lattice, more importance is given for orientation selectivity. So this paper used the orientation selectivity filter like Gabor filter for the purpose of edge detection on hexagonal domain.Gabor expansion is a time frequency analysis method which combines both the time/space and frequency information. Gabor expansion can be implemented as a multi-channel filter.

$$g(x,y;\omega,\theta,\sigma)=\frac{1}{2\prod\sigma^2}\exp\left(\frac{-(x^2+y^2)}{2\sigma^2}\right)\exp(i(w_x\cos\theta+\omega_y\sin\theta)) \qquad (1)$$

The Gabor filter can be mathematically represented as (1) where Gabor parameters like ω, θ and σ represents radial frequency, orientation and spatial extension respectively. Due to the three axis of symmetry of hexagonal grid we should choose three different orientations along 0^0, 60^0 and 120^0. The central frequency is selected according to the image dimension. The radial frequencies are all 1 octave apart. Low frequency corresponds to smooth variations and constitutes the base of an image and high frequency presents the edge information which gives the detailed information in the image. Hence, this study neglects the very low radial frequencies. Using these frequencies and orientations, the Gabor filter Multi-channel system can present an image in various orientations and frequencies. For performing edge detection operation on hexagonal domain using Gabor filters, the image is convolved with gabor filter bank to obtain the gabor filtered image along three different orientation. Then we find the edge detection of the resultant superimposed Gabor filtered image.

III. Performance evaluation

In this work, the performances of edge detection on rectangular and hexagonal grids are computed using Gabor Wavelets. The performance was compared based on the Peak Signal-to-Noise Ratio and elapsed time.

A. Peak Signal to Noise Ratio (PSNR)

PSNR is used for quantitative comparison. In edge detection the higher value of PSNR indicates more edge pixels are identified.

$$\frac{\sum_i\sum_j (X_{ij}-Y_{ij})^2}{N}$$

Where N is the size of the image, X is the processed image, and v is the original image. In this equation the term $\frac{\sum_i\sum_j (X_j - V_j)^2}{N}$ known as Mean Square Error (MSE). It indicates the average difference of the pixels throughout the image.

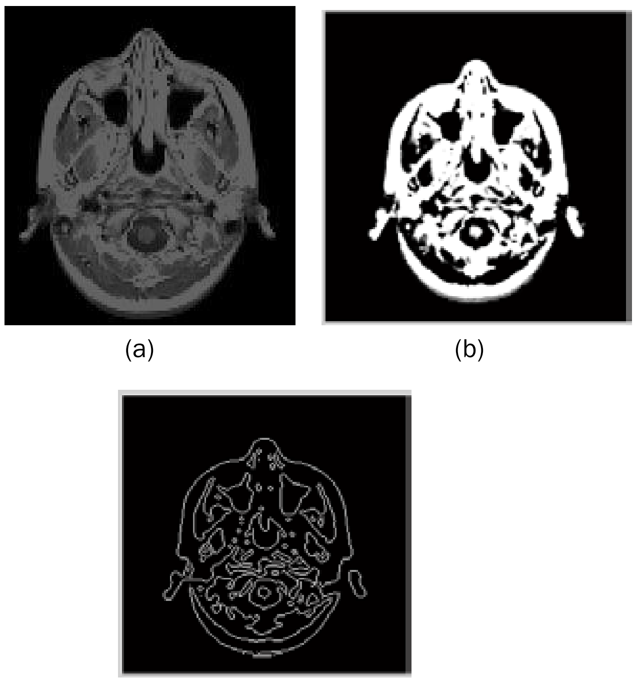
IV. Results and Discussion

Application of wavelets on rectangular grid images results in the decomposition of image to various frequency components.

(a) (b) (c)

Fig.3 : (a) Original Image (b) Wavelet decomposition (c) Edge detected image.

The fig. 3 shows the decomposition of Lena image. Upper left part shows low frequency (approximation) component and the other three gives to high frequency component which corresponds to edges. The superimposition of these three high frequency part gives the edge detected image. Due the different axis of symmetry of hexagonal lattice we used the orientation selectivity filter like Gabor filter for the purpose of edge detection on hexagonal domain. For the comparative study Gabor based edge detection on rectangular domain is also considered.



(a) (b)

(c)

Fig.4: (a) Original Image (b) Gabor filtered image (c) Edge detected image on rectangular domain

In Fig.4 (b).Gabor filtered image is a super imposed image of four orientations 0^0, 45^0,90^0, 135^0 in rectangular domain .

In hexagonal domain the input image is converted into hexagonal

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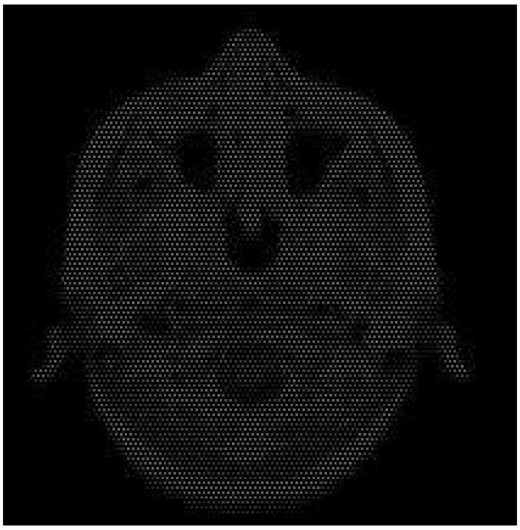
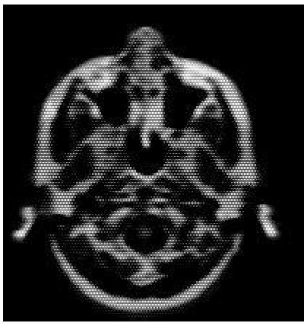
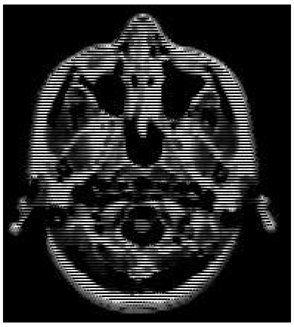
resampled image by half-pixel shift method. In Fig.5(a) hexagonal resampled image is shown and the Gabor filtering is done in 3 different orientations since hexagonal sampled grid has 3 directional symmetry in 0^0,60^0,120^0 orientations.



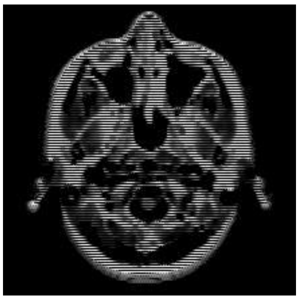
(a)



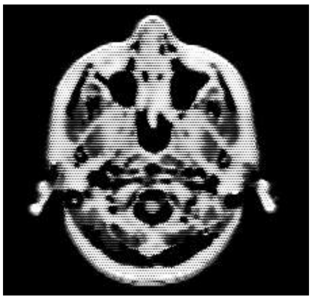
(b)



(c)



(d)



(e)

(f)

Fig. 5: (a)Hexagonal resampled Image (b) Gabor filtered image in 0^0 (c) Gabor filtered image in 60^0 (d) Gabor filtered image in 120^0 (e) Superimposed Gabor filtered image (f) Edge detected image on hexagonal domain

Table 1 : Analysis of Gabor based Edge detection

Test Data	Sampling	PSNR	Elapsed Time (in seconds)
mri.tif	Rectangular	68.8	4. 26
	Hexagonal	69.1	2..5
bacteria.tif	Rectangular	56.7	4. 3
	Hexagonal	58.4	2. 6
wheel. jpg	Rectangular	58.4	6. 5
	Hexagonal	60.4	2. 5

The results show that using Gabor filter the edge detection on hexagonal domain detects more edges compared to rectangular domain. In the performance wise hexagonal grid gives better PSNR also elapsed time is reduced for hexagonal grid.

V. Conclusion

In the modern image processing, image edge is basic image features, and is the base of analysis for understanding image. The structure information of an object boundary status can be preserved by edge detection, and can provide the basis for image cutting and features extracting. Traditional methods for edge detection, such as Prewitt, Sobel, Roberts, Canny are very sensitive to noise in the image, also time and memory consuming. They cannot distinguish edges of different significance as they primarily focus on the coupling between image pixels on a single scale. Wavelet transform has the spatial and the frequency domain characteristics and multi-scale analysis abilities, and very suitable for image processing especially for detection of the sharp signals. The traditional wavelet transform is time and memory consuming. By applying wavelet transform using Gabor filters it is possible to detect edges in different orientation so that it can give the correct edge information. Experimental results show that the edge detection on hexagonal grid gives better performance in terms of PSNR and elapsed time. So by utilizing the advantages of hexagonal domain in image processing it is possible to get improved results.

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