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RESEARCH ARTICLE

PERFORMANCE EVALUATION OF EDGE DETECTION TECHNIQUES FOR SQUARE PIXEL AND HEXAGON PIXEL IMAGES

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ABSTRACT

In today's world all the imaging data or information is processed and stored in a digital form. The digital imaging used in many applications like forensic imaging, medical imaging and computer graphics etc. The image is first captured by the hardware and then converted into digital form and stored in memory device. The digital images are represented and stored in the form of square pixel. The square pixel image is formed by using the average of square area of smaller square pixel. Another form to digitize an image is hexagonal pixel. The hexagonal pixel structure is preferred over the square pixel structure, due to its advantages like angular resolution, higher quantization error and less aliasing effect. In this paper, firstly picture quality of image using hexagonal pixel structure is reviewed. Another contribution in this paper is comparison between various edge detection techniques on square pixel structure, hexagonal pixel structure and enhanced hexagonal pixel structure using Gaussian filter. The experimental result shows that the image edge detection significantly reduces the amount of data and filters out useless information.

INTRODUCTION

A digital image represents the real world which contains thousand of pixels in the form of square pixel structure. The square pixels have many advantages like picture symmetry, less calculation, easy to store and to implement. But due to its disadvantages like aliasing effect, quantization error, connectivity between the pixels with respect to the central pixel, less angular resolution and less symmetry, the square pixel structure in less advantageous. Hexagonal image representation posses special computation features like higher degree of circular symmetry, uniform connectivity, reduced need of storage, greater angular resolution that are patent to the human visual system. It is an alternate tessellation scheme which have been proven a better efficiency and less aliasing effect, (Mersereau *et al*., 1979). The hexagonal pixel structure matches with the natural occurrences such as bee hives and the structure of simple eye unit called 'ommatidia' present in the hard shielded animal such as crab are also in the shape of hexagon (Buschbeck *et al*., 1999). Due to these occurrences, hexagonal pixel structure would provide better quality than the square structure. Golay (1969), proposed a parallel computer based on hexagonal modules which require fewer interconnections as compared to a similar square based architecture.

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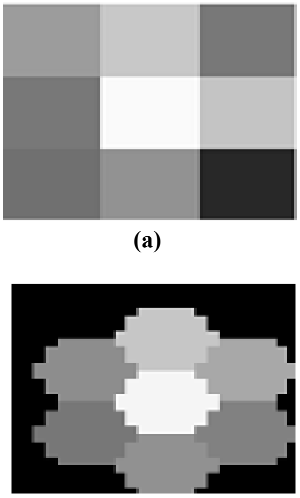
The main reasons for using a hexagonal coordinate system for image processing are hexagon's consistent connection with their neighbors and the ease of representing natural shapes using hexagons (Mersereau *et al*., 1979; Buschbeck *et al*., 1999; Golay *et al*., 1969). In a normal square-pixel system, a pixel's neighbors have two different levels of connectivity - they are either 1 pixel away, or $\sqrt{2}$ pixels. Using a hexagonal coordinate system means that each neighbor is exactly 1 pixel away, and so algorithms can treat them all the same. The natural representation of curves in hexagonal coordinate systems allows many visual operations to be performed more easily; examples are edge detection and shape extraction. 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. In the past years, there have been various attempts to simulate a hexagonal grid on a regular rectangular grid device. The simulation schemes include those approaches using rectangular pixels (Horn *et al*., 1986), pseudo hexagonal pixels (Wuthrich, Stucki *et al*., 1991), mimic hexagonal pixels (He *et al*., 1999) and virtual hexagonal pixels (Hintz, He *et al*., 2000) In hexagonal grid each unit is a set of seven hexagons and the image pixels are closer to each other in hexagonal image thus making the edges more clear and sharp as compared to square (or rectangular) image whose architecture uses the set of 3x3 vision unit as shown below in a Figure.1 below Edge is a basic feature of image. Edge detection refers to the process of identifying and locating sharp discontinuities in an image. The shape of edges in image depends on many parameters such as geometrical and optical properties of the object, the illumination conditions, and the noise level in the images (Buschbeck *et al*., 1999). Edge detection depends upon the relation of pixel with its neighbor, extracts and localizes the pixels so that a large change in image brightness takes place. A pixel is said to be unsuitable in terms of edge if the brightness around a pixel is similar (or close). Otherwise, the pixel may represent an edge. Many edge detection algorithms have been proposed and implemented. These algorithms differ from each other in many aspects such as computational cost, performance and hardware implementation feasibility.



(a)

(b)

Fig. 1.(a) Square Pixel Image (b) Hexagon Pixel Image

In the hexagonal pixel structure, edge detection plays a important role for detecting meaningful discontinuities in gray level. An edge is defined as 'a set of connected pixels that lie on the boundary between two regions', edge is a 'local' concept (Woods, Gonzalez *et al*., 2002). In hexagonal pixel structure, the edge detection operations were performed on the hexagonally sampled image (Buschbeck *et al*., 1999), which is collected by converting rectangular pixel structure to the hexagonal pixel structure. Image edge detection is operated on a 3 X 3 pattern grid, so it is efficient and easy to implement. In hexagonal pixel structure uses hexagonal masked operators for edge detection. These hexagonal masks are applied on the images which is represented using spiral addressing scheme. The implemented work methodology is as shown below in Figure 2.

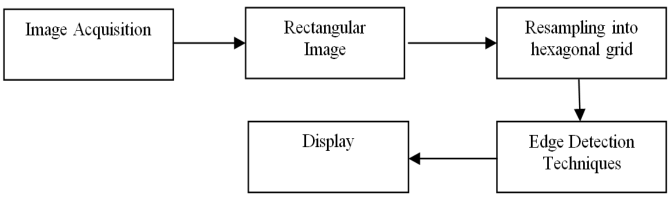


Fig.2. Work methodology

Construction of hexagonal pixels from square pixels

For the construction of hexagonal pixel each square pixel is firstly separated into 7x7 smaller pixels called sub-pixels (He, Hintz, Wu, Wang, Jia, *et al.,* 2006). Each sub-pixel has same light intensity as that of a pixel from which the sub-pixels are separated. A hexagonal pixel is called 'hyperpel' and each virtual hexagon pixel is formed by 56- different sub-pixels forming the hexagonal structure as shown in figure below.

The size of each hexagon constructed pixel is given as:
56-46/56 = 12.5 %.

This means, the number of hexagonal pixels is 12.5% less than the number of square pixels to cover up an image and each constructed pixel is 12.5% bigger than the each square pixel.

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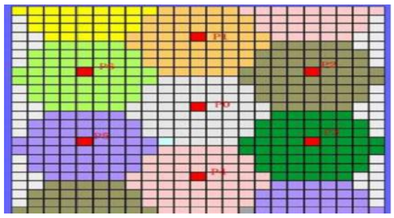
		#	#	#	#	#		

(a)



(b)

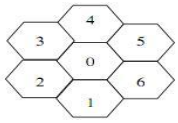
Fig. 3(a) Structure of Single Hexagonal Pixel (b) Structure of Hexagonal Pixels

Hexagonal image representation

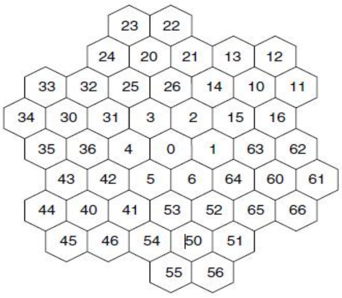
Image re-sampling is the technique used for converting a square lattice to a hexagonal lattice (He, Hintz *et al*., 2006). Due to many problems such as equal distance from the centre pixel, lack of hardware for capturing and displaying hexagonal images limits the use of hexagonal pixel structure, that affects the advance research on hexagonal pixel architecture (Wang, Hintz, *et al*., 2005). There have been several techniques to represent a hexagonal grid in place of square (rectangular) grid. In this paper, spiral addressing is used to represent hexagonal pixel structure.

Spiral Addressing

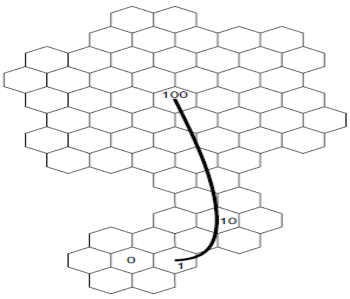
In order to properly address and store hexagonal images data, one-dimensional addressing scheme for a hexagonal structure, together with the definitions of two operations, Spiral Addition and Spiral Multiplication is proposed by Sheridan (Sheridan, Hintz, Alexander, *et al*., 2000).This hexagonal structure is called the Spiral Architecture (SA). The first step in Spiral Addressing formulation is to label each individual hexagon with a unique address. This is achieved by a process that is applied to a collection of seven hexagons. Each of these seven hexagons is labeled consecutively with addresses 0, 1, 2, 3, 4, 5 and 6, (as shown in Figure 4).



(a)



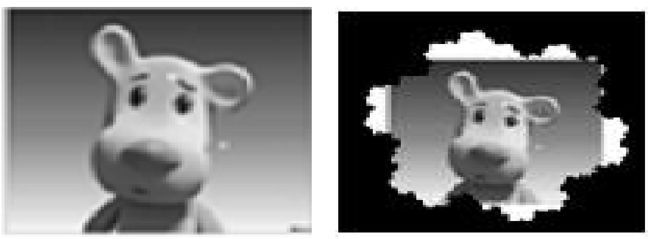
(b)



(c)

Fig.4. (a) A collection of seven hexagonal pixels with unique address (b) Spiral architecture and spiral addressing with unique address (c) Spiral rotating direction through 1, 10, and 100

The spiral structure is frame to place six additional collections of seven hexagons about the addressed hexagons and multiply each address by 10. For each new collection of seven hexagons, the central address for the first seven hexagons is labeled as hexagon. The repetition of these steps allows to form a collection of hexagons with the powers of seven with uniquely assigned addresses. This pattern generates the Spiral architecture. The spiral rotation direction is followed through 1, 10 and 100 as shown in Figure 4.(b), in which the location of hexagon pixel with a given spiral address starting from the central pixel of address 0 (Horn, 1986). For example, to find the location of the pixel with spiral address 443, we need only know the locations of the pixels with spiral addresses 400, 40 and 3. The example of spiral addressing on an image is as shown below in Figure 5.



Square pixel image	Hexagonal addressed image

Fig. 5. Example of spiral addressing

Edge detection operators

Sobel Edge Detector

The sobel edge detector method detects the edges by taking the maximum and minimum in the first derivative of the gray level gradiant in the spatial domain (Sobel *et al*., 1978). The sobel edge detectors have no smoothing fsilter, and they are only based on a discrete differential operator (Gonzalez and Woods, 1992). This method performs 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges. It consists of a pair of 3×3 convolution mask which contains kernels and each kernel is simply the other rotated by 90°.

Prewitt Edge Detector

The Prewitt edge detector is a gradient based edge detector and very similar to the sobel operator. Prewitt edge detector is a correct way to estimate the magnitude and orientation of the edge (Gonzalez, Woods *et al.,* 1992). These kernels are designed to respond maximally to the edges running at 45° to the pixel grid. The operator detects the edges in both horizontal and vertical directions, and then combines the information into a single matrix. The detector is considered to be poor due to its bad approximation to the gradient operator. However, the ease of implementation and low computational cost overcome these disadvantages.

Robert's Edge Detector

Robert's edge operator performs 2-D spatial gradient measurement on an image and provides best results with binary images. The operator consists of a pair of 2×2 convolution kernels. One kernel is simply the other rotated by 90° (Roberts *et al*., 1965) and applied separately to the input image, to produce separate measurements of the gradient component in each orientation. It returns edges at those points where the gradient of the image is maximum which means it highlights the regions of high spatial frequency which often correspond to edges.

Laplacian of Gaussian Edge Detector

The Laplacian is a 2-D isotropic detector and performs 2^{nd} spatial derivative measurement on an image. The Laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection. The operator normally takes a single gray level image as input and produces another gray level image as output.

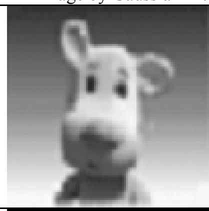
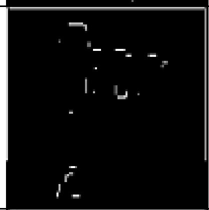
Canny edge detector

Canny edge detection operator is the most powerful edge detector. The canny edge detector detects the edges by isolating noise from the image without affecting the features of the edges in the image and then applying the tendency to find the edges and the critical value for the threshold (Canny *et al*., 1986). The magnitude, or edge strength, of the gradient is then approximated using the formula:

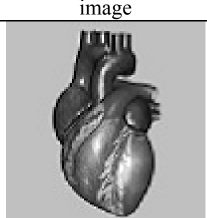
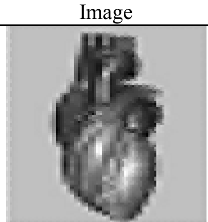
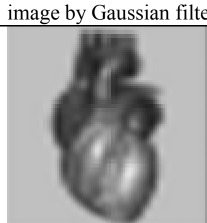
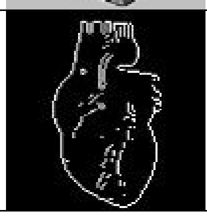
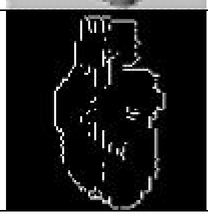
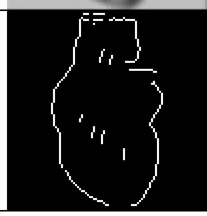
$$|G| = |Gx| + |Gy|$$

EXPERIMENTAL RESULTS

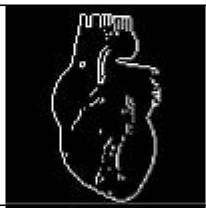
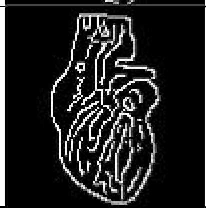
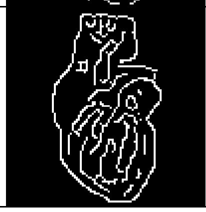
Experiment No.1

S.No.	Edge detection operators	Square pixel Image	Hexagonal pixel Image	Hexagonal Pixel Enhanced image by Gaussian filter
01	Images			
02	Sobel			
03	Prewitt			
04	Roberts			
05	Laplacian of Gaussian			
06	Canny			

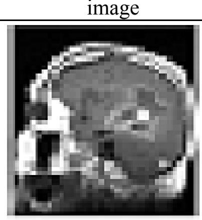
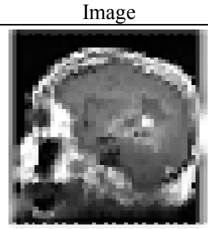
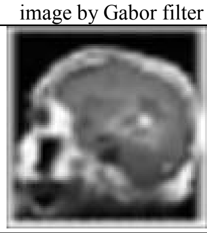
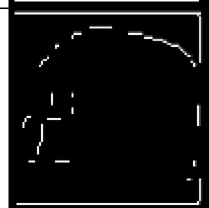
Experiment No.2

S.No	Edge Detection Operators	Square Pixel image	Hexagonal pixel Image	Hexagonal Pixel Enhanced image by Gaussian filter
01	Images			
02	Sobel			

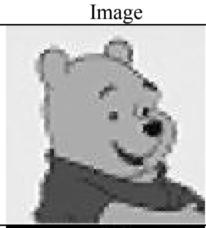
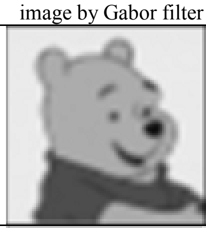
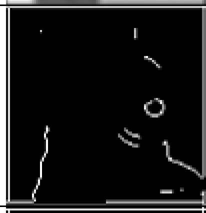
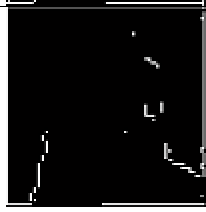
Continue…………

03	Prewitt			
04	Roberts			
05	Laplacian of Gaussian			
06	Canny			

Experiment No.3

S.no	Edge Detection Operators	Square Pixel image	Hexagonal pixel Image	Hexagon enhanced image by Gabor filter
01	Images			
02	Sobel			
03	Prewitt			
05	Laplacian of Gaussian			
06	Canny			

Experiment No.4

S.No	Edge Detection Operators	Square Pixel image	Hexagonal pixel Image	Hexagon enhanced image by Gabor filter
01	Images			
02	Sobel			
03	Prewitt			
04	Roberts			
05	Laplacian of Gaussian			
06	Canny			

Result of Example.1

S.No	Operators	Square Pixel Image		Hexagonal Pixel Image		Hexagonal Enhance Pixel Image By Gaussian Filter	
		MSE	PSNR	MSE	PSNR	MSE	PSNR
01	Sobel	0.3590	52.5796	0.3328	52.9091	0.3200	53.0794
02	Prewitt	0.3589	52.5808	0.3330	52.9064	0.3199	53.0801
03	Roberts	0.3518	52.6679	0.3317	52.9231	0.3141	53.1607
04	Gaussian	0.3460	52.7400	0.3307	52.9460	0.3068	53.2624
06	Canny	0.3518	52.6681	0.3304	52.9308	0.3140	53.1611

Result of Example.2

S.No	Operators	Square Pixel Image		Hexagonal Pixel Image		Hexagonal Enhance Pixel Image By Gaussian Filter	
		MSE	PSNR	MSE	PSNR	MSE	PSNR
01	Sobel	0.4294	51.8024	0.4174	51.9253	0.3979	52.1326
02	Prewitt	0.4291	51.8056	0.4172	51.9269	0.3980	52.1322
03	Roberts	0.4306	51.7900	0.4187	51.9115	0.3915	52.2034
04	Gaussian	0.4206	51.8917	0.4138	51.9625	0.3899	52.2218
06	Canny	0.4377	51.7191	0.4242	51.8552	0.3952	52.1628

Result of Example.3

S.No.	Operators	Hexagonal Pixel Image		Hexagonal Pixel Image		Hexagonal Enhance Pixel Image By Gaussian Filter	
		MSE	PSNR	MSE	PSNR	MSE	PSNR
01	Sobel	0.3086	53.2367	0.3005	53.3527	0.2362	54.4005
02	Prewitt	0.3092	53.2286	0.3010	53.3458	0.2361	54.3989
03	Roberts	0.3106	53.2088	0.2909	53.4927	0.2365	54.3926
04	Gaussian	0.2713	53.7959	0.2608	53.9675	0.2286	54.5409
06	canny	0.2958	53.4202	0.2882	53.5342	0.2373	54.3782

Result of Example.4

S.No.	Operators	Hexagonal Pixel Image		Hexagonal Pixel Image		Hexagonal Enhance Pixel Image By Gaussian Filter	
		MSE	PSNR	MSE	PSNR	MSE	PSNR
01	Sobel	0.5487	50.7376	0.5396	50.8104	0.4903	51.2259
02	Prewitt	0.5482	50.6394	0.5316	50.3458	0.4902	51.2264
03	Roberts	0.5567	50.6745	0.5394	50.8114	0.4984	51.1553
04	Gaussian	0.5288	50.8982	0.5154	51.0091	0.4768	51.3474
06	Canny	0.5431	50.7817	0.5281	50.9038	0.4925	51.2071

Conclusion

In this paper evaluation of various edge detection techiniques that are Sobel, Robert, Prewitt, Laplacian of Gaussian and Canny are applied on the square pixel, hexagon pixel and enhance hexagon pixel image by gaussian filter. From the above results, it has been shown clearly that the Sobel, Prewitt, Roberts, Canny provide low quality edge maps as compared to Laplician of gaussian. Comparison is done on the basis of two parameters PSNR and MSE. For an effective edge detection, PSNR value should be high and MSE should be low. Among the investigated method, the Laplacian of gaussian method detects both strong and weak edges of hexagonal pixel and enhanced hexagonal pixel as compare to square pixel.

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