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Review on Performance Analysis of Square Pixel and Hexagonal Pixel Structure in Image Processing

Snehali A. Dakhore
P. R. Pote (Patil) Welfare & Education Trust's college of Engineering & Management, Amravati
Department of Computer Science & Engineering
Amravati, India
snehali.dakhore@gmail.com

Prof. K. B. Bijwe
P. R. Pote (Patil) Welfare & Education Trust's college of Engineering & Management, Amravati
Department of Computer Science & Engineering
Amravati, India
komalbijwe@gmail.com

***Abstract*—** Image processing is very important in several applications and have been using in them very efficiently. In image processing most applications data is collected and displayed in square pixels but most of the time the feature extraction from an image like image segmentation, image detection, edge detection, texture recognition, etc becomes difficult to recognize in square pixel image. So, one new approach called hexagonal pixel structure has been designed to overcome the problems of square pixel structure. Hexagon pixel is advantageous because of its higher symmetry, higher sampling efficiency, equidistance, greater angular resolution, less aliasing effect, consistent connectivity. Out of the many advantages for the hexagonal pixel structure most important is its resemblance with the arrangement of photoreceptors in the human eye. Due to the arrangement the amount of pixels required is very less. So, in this work, quality representation of image which having square pixel structures are compared with images having hexagonal pixel structure.

Keywords- — *Image processing, Tessellation scheme, Square pixel, Hexagonal pixel.*

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I. INTRODUCTION

Conventionally, images are digitized and stored as a rectangular array of values. The image is sampled at each point on a two dimensional grid storing intensity and implicit location information for each sample. The rectangular grid is by far the most dominant of any grid structure in image processing although the hexagonal structured pixel grid is considered to be superior to the rectangular grid system in many respects, including greater angular resolution [2].

There exist only two possible regular tessellation schemes to cover a plane without overlapping among the samples and gaps between them [1]. They are the tessellation with squares and with hexagons. Figure1 is the square, which is familiar and usual because it is aligned with the standard Cartesian axes, which helps to make operations simple. The tessellation in Figure2 is the hexagonal case. It is believed to be the most efficient tessellation scheme among them because of its advantages like smaller quantization error consistent connectivity pixel is equidistantly adjacent to their six neighbours along the six sides of the pixels and grater angular resolution. In addition to these advantages the primary motivation behind using a hexagonally re-sampled image is that retina of the human eye closely resembles a hexagonal grid space [3]. So we can obtain natural behaviour to realize the computer vision by using the hexagonally sampled images.

Researchers have been studying the feasibility of introducing the hexagonal grid in the area of image processing. There are various pixels tessellation schemes available to represent digital images. Hexagonal grid is also a pixel tessellation scheme which is efficient than any other schemes. Normally digital images are mapped on square lattice and here we are changing the square lattice to hexagonal lattice for the hexagonal image processing. Hexagonal coordinate system is well suited for creating the artificial human visual system, because the arrangements of the photo receptors in the human retina are in hexagonal form.

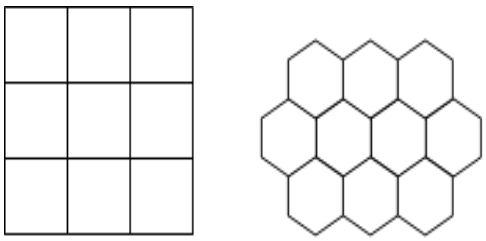

Figure 1. (a) Square Pixel Structure
(b) Hexagonal Pixel Structure

II. LITERATURE SURVEY

Since the cells in human retina have hexagonal structure, the image developed in the retina has hexagonal shaped pixels. In addition, hexagonal geometry has some advantage like higher sampling efficiency, consistent connectivity and higher angular resolution. Due to these reasons many researchers have studied the possibility of representing digital images with hexagonal pixels [8]. But one difficulty we faced in hexagonal image processing is the non-availability of hardware for acquiring hexagonal images. So,

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rectangular grid to hexagonal grid conversion has to be done before performing hexagonal image processing. Different techniques are now available for crating hexagonal structure images. Some of these simulations schemes are re-sampling method, pseudo hexagonal pixel [6, 4], virtual hexagonal structure, and mimic hexagonal structure.

In order to compare the visual effect of hexagonal pixel and square pixel C.A. Wuthrich and P. Stucki proposed a pseudo hexagonal pixel structure [4]. In this structure a hexagonal pixel is simulated using many square pixels. Virtual hexagonal structure was proposed by Q. Wu, X. He and T. Hintz in their paper titled _Virtual Spiral Architecture [7, 14]. In this method, the image in conventional square grid is mapped into virtual spiral architecture. The processing is done using this virtual structure and after processing it is converted back into square grid.

III. TECHNIQUES TO CONVERT SQUARE PIXEL TO HEXAGONAL PIXEL

There are numbers of techniques available which can convert the square pixel to hexagonal pixel.

- Resampling method
- Pseudo hexagonal pixel
- Virtual hexagonal structure
- Mimic hexagonal structure

1. Resampling Method:

In this technique, every alternate row is shifted to half the width of new pixels. This technique has regular property which shows approximate 60 degree angle with neighboring pixels. The central pixel shows equidistance property with its neighboring horizontal pixels and its value is equal to 1 but neighboring diagonal pixel do not represent equidistance property. Due to this reason this technique has a loss in image resolution.

2. Pseudo Hexagonal Structure:

The pseudo hexagonal structure is design from square pixels in the aspect ratio of 12:14. The pseudo hexagonal structure is using only one rectangular pixel to represent a hexagonal pixel.

3. Virtual Hexagonal Structure:

This technique is using a virtual spiral architecture in which spiral architecture is used during the processing part. The normal image in the traditional square grid is mapped into virtual spiral architecture and does the processing. Once the processing is done it is converted back into square grid and is displayed. It is different from all the above mimicking method because it will neither create any distortion nor reduce resolution.

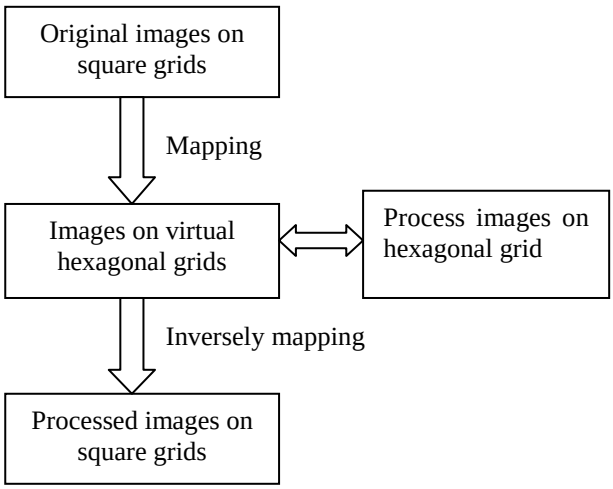

Figure 2. Image processing on virtual spiral architecture

4. Mimic Hexagonal Structure:

In this method simulation one hexagonal pixel consists of four traditional square pixels and its grey level value is the average of the involved four pixels. This method preserves the important property of hexagonal architecture that, each pixel has exactly six surrounding neighbours.

Since the grey-level value of the mimic hexagonal pixel is taken from the average of the four corresponding square pixels, this mimic scheme introduces loss of resolution. Also the equidistance property of hexagonal representation is lost in this method. Fig.5 shows a cluster of 7 mimic hexagons.

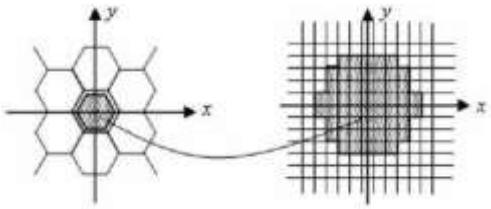

Figure 3.Pseudo hexagonal pixel

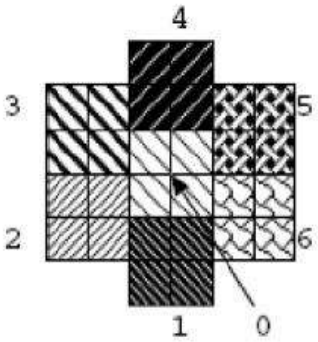

Figure 4.Cluster of 7 mimic hexagons

IV. BENIFITS OF HEXAGONAL PIXEL STRUCTURE OVER SQUARE PIXEL STRUCTURE

Digitization is one of the hardest tasks which scientists were worried about in image processing. Because the real scene will be in a continuous plane and the images are on a digital screen with discrete points. In the process of digitization, the

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discrete points referred as pixels have to be arranged on the screen which should be properly addressed. The arrangement of the pixels should be regular and its representation on the plane should be efficient also.

1. Fixed Connectivity:

In square pixel structure, there are two types to define neighbors of a pixel:

- 4-way connectivity
- 8-way connectivity

In 4-way connectivity, four neighboring pixels are connected through edges. In 8-way connectivity, in addition to edges, four other are connected through corners.

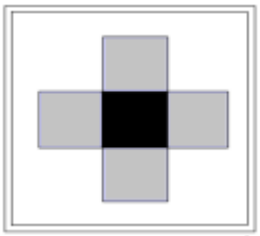

Figure 5.Four-Way Connectivity

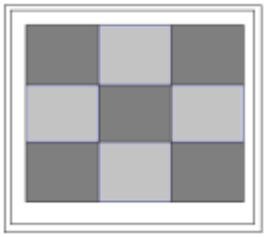

Figure 6.Eight-Way Connectivity

In hexagonal pixel structure, there exists only 6-way connectivity. In 6-way connectivity the central pixel is connected to all six neighboring pixels through its edges.

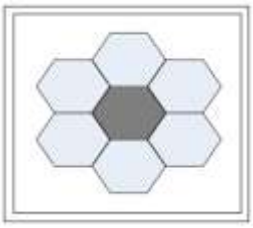

Figure 7.Six-Way Connectivity

2. Equidistance:

With the introduction of neighborhood relation, distance function can be easily measured. In square grid we have two types of distances, where the distance between adjacent pixels in the diagonal direction is √2 times that of in the horizontal (or vertical) direction which is a unit distance .While in hexagonal case, each hexagonal pixel has only six neighboring pixels and each pixel is equidistantly adjacent to their six neighbors along the six sides of the pixels. The centroid of the middle pixel is at the same distance from the centroids of the six adjacent pixels.

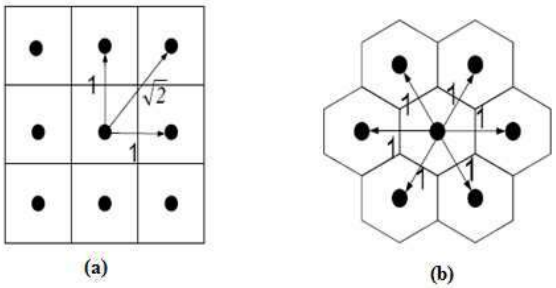

Figure 8. Distance in (a) square grid and (b) Hexagonal grid

3. Higher Symmetry:

Many morphological operations are developed by Serra and are been widely used in Image processing .They studied the same on different grids and identified the fact that hexagonal grid has higher symmetry and simple operations.

4. Greater Angular Resolution:

Image processing on a hexagonal lattice is also advantageous due to its greater angular resolution to represent curved objects. It has been noted that hexagons offer greater angular resolution as the nearest neighbors of the same type are separated by 60 degree instead of 90 degree. An example showing a familiar curved figure and a representation on hexagonal and square lattices are shown in Figure13.

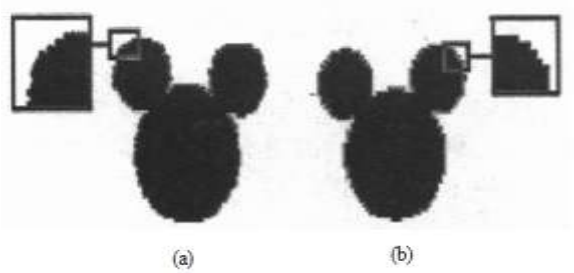

Figure 9. Curved figure represented in (a) Hexagonal grid and (b) Square grid

5. Aliasing Effect:

Aliasing will occur to the images whose sampling rate is not sufficient. Peterson and Middleton [10] found out the fact that the least samples are required for the reconstruction of a wave number limited signal in hexagonal lattice. From this it is clear that square lattice is not the best one. Mersereau [12] also concluded that signals in Fourier space requires only 13.4% lesser samples to represent the same image data in hexagonal grid compared to the rectangular one. By using this advantage it is clear that the storage space required will become less and the computation cost will also become less. Vitulli [15] also investigated the sampling efficiency using hexagonal grid and concluded that it's the same as Mersereau explained in his work. Vitulli also found out that using the hexagonal grid, wider spectra of signal can be sampled without aliasing with fewer amounts of samples.

6. Quantization Error:

In computer vision, quantization error is a very important measurement to investigate the merits of different types of sensory configurations in order to find which spatial sampling would introduce less quantization error into

computations. Kamgar-Parsi [11,13] developed formal expressions for estimating quantization error in hexagonal spatial sampling and found that, for a given resolution capability of the sensor smaller quantization errors than square sampling.

CONCLUSION

In this paper present that how to perform the analysis between square pixel and hexagonal pixel structures in image processing and also use of hexagonal pixel based images has gained much attention in recent years in image architecture. In this research work by using above technique there is better visualization with hexagonal sampling. Here shown that hexagonal is better than square pixel, it means it overcome the disadvantages of square pixel. And also give the benefit of hexagonal pixel. Hexagonal pixel structure has three dominant axes which are sixty degree apart which means small angle of rotation hexagon pixels represents images better than square pixels.

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