RESEARCH ARTICLE OPEN ACCESS

Comparison between Square Pixel Structure and Hexagonal Pixel Structure in Digital Image Processing

Illa Singh[1], Ashish Oberoi[2]
M.Tech[1], Final Year Student, Associate Professor2
Department of Computer Science and Engineering
Maharishi Markandeshwar University
Mullana, Ambala
Haryana - India

ABSTRACT

In image processing, for most of the applications; the images are displayed using square pixels. The various improvements in technologies like CCD and increasing processing capabilities of graphic devices give arise to hexagon pixels which are becoming attractive for various practical applications. Hexagon grid is an alternative tessellation scheme besides the conventional square grid for sampling and representing images. Hexagon pixel is advantageous over square pixel because of its higher symmetry, higher sampling efficiency, equidistance, greater angular resolution, less aliasing effect, consistent connectivity. Also one of the most important advantages of using hexagon pixel is its resemblance with the arrangement of photoreceptors in the human eye and with such an advantage the number of pixels required is less. So, in this paper, quality representation of images which having square pixel structure are compared with images having hexagonal pixel structure.

Keywords:-Image processing, tessellation schemes, square pixel, hexagonal pixel

I. INTRODUCTION

Traditionally, image processing has involved the use of square pixels. In most of the applications of image processing, data is gathered and arranged in the form of square pixels [1]. Image sampling using square pixel has advantages like less calculation, easy to implement. In addition to these advantages, it has drawbacks like inconsistent connectivity, less angular resolution, aliasing effect which makes it less pertinent to vision process of human eye.

Hexagon pixel is an alternative tessellation scheme besides the traditional square pixel. Sampling and representing images using hexagon pixel has been proved to have less aliasing effect and better efficiency [2]. Human eye captures information to process visual input with the help of RETINA which is located on the inner surface of eye. A small region within retina, which is called FOVEA, consists of high density of CONES, are placed and shaped in a hexagon arrangement [3]-[5]. This hexagon arrangement results in sharp vision for capturing information.

In spite of replicating the characteristics of human eye, hexagon pixel have other advantages over square pixel which are greater angular resolution, equidistance property from centre pixel to all neighboring pixel, consistent 6-way connectivity, higher symmetry than square pixel, less number of pixels are required to represent the image which results in less computation time and needs less storage space. Hexagonal image architecture is a set of seven hexagons compared with traditional square image architecture using a set of 3×3 units is shown as:

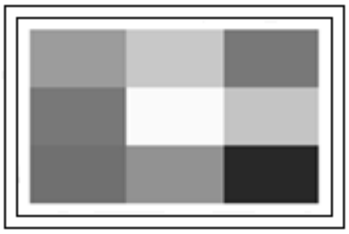

FIG. 1 SQUARE PIXEL STRUCTURE

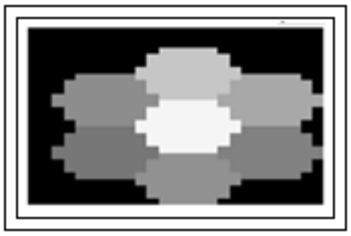

FIG. 2 HEXAGONAL PIXEL STRUCTURE

II. POSSIBLE TESSELLATIONS

To tile a plane which is regular and whose samples do not overlap with each other and with its gaps, there exist three possible tessellation schemes which are

- Triangular Tessellation
- Square Tessellation
- Hexagonal Tessellation

Any other tessellation will result in inconsistency in neighboring connectivity, gaps, overlapping among samples.

1. *Triangular Tessellation*

Triangular tessellation exhibits tight arrangement among the other two tessellations. This tessellation shows more information in same image as compared to other tessellations. This is a complicated scheme which makes it unattractive. The central pixel of triangular tessellation has 12 neighbors which can be divided into two categories:

- One that have an edge in common with the central pixel.
- Other that only has a corner in common.

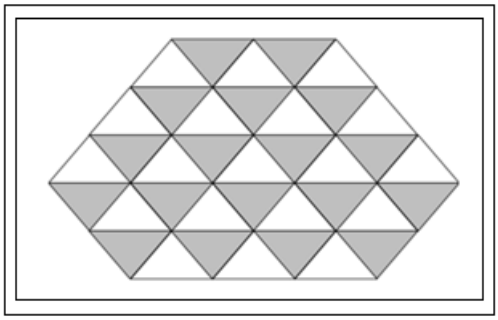

FIG. 3 TRIANGULAR TESSELLATION

2. *Square Tessellation*

Square tessellation is the simplest scheme among other two tessellations. This scheme uses Cartesian coordinate system. The shape of pixels used is commonly square and these fit together. Square tessellation has following important points:

- They do not leave any gaps because of its shape.
- They have sides of equal length.
- They can be mapped into axes: horizontal and vertical.

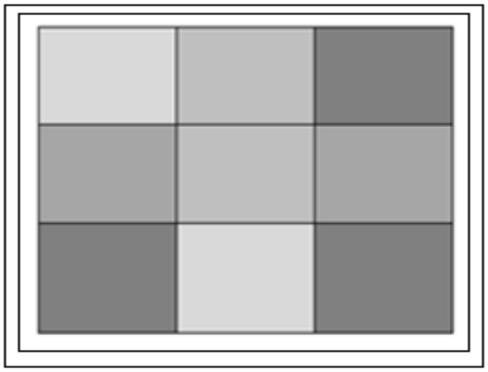

FIG. 4 SQUARE TESSELLATION

3. *Hexagonal Tessellation*

Hexagonal tessellation exhibits tight and compact packing of pixels among other two schemes. Hexagonal lattices resemble the pattern of photoreceptors in the human eye. This implies that hexagonal tessellation are useful for capturing more information to process visual input performed by eye to brain and also in simulating when visual processing on image data is performed by brain.

In hexagonal images, pixels are closer to each other which make the edges more sharp and clear compared to others. Hexagon image processing has following beneficial points:

- It reduces the complexity and makes processing fast.
- It takes less storage space.
- To achieve accuracy.
- Hexagon pixel array have three dominant axes which are 60 degree apart whereas square has only two axes which are 90 degree apart.
- Extracting the features of image can be done more accurately.

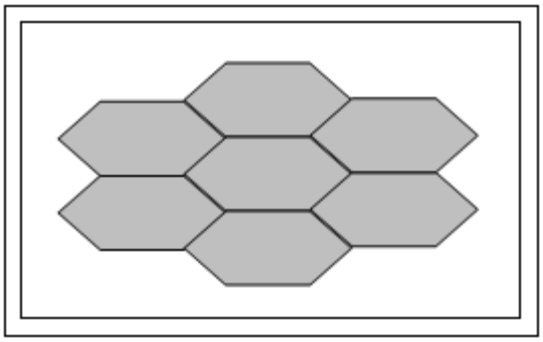

FIG. 5 HEXAGONAL TESSELATION

III. BENEFITS of HEXAGONALPIXEL STRUCTURE OVER SQUARE PIXEL STRUCTURE

Digitization is very important in image processing. In digitization process, discrete points which are also known as pixels have to be arranged on the screen with proper addressing. The arrangement should be regular and it should be represented efficiently.

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.

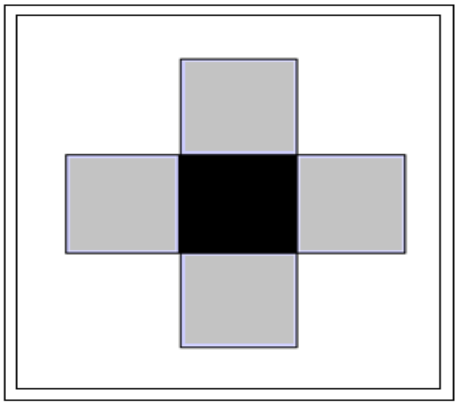

FIG. 6 FOUR-WAY CONNETIVITY

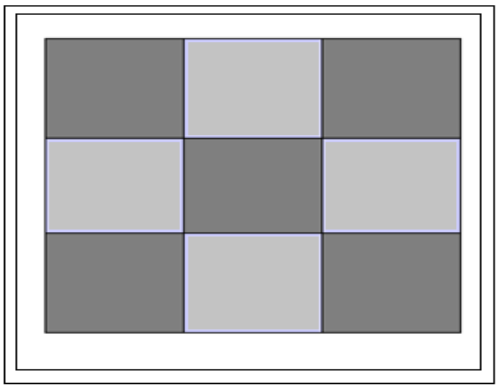

FIG. 7 EIGHT-WAY CONNECTIVITY

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.

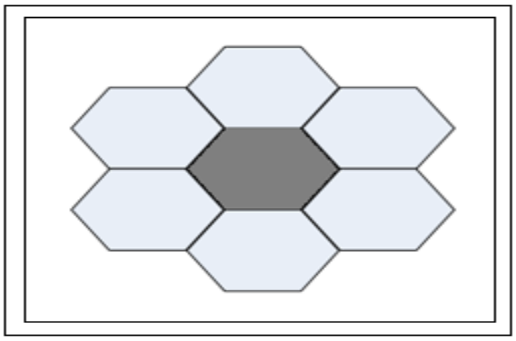

FIG. 8 SIX-WAY CONNECTIVITY

2. *EQUIDISTANCE*

In square pixel structure, there are two ways to measure distance. The distance of horizontal and vertical direction is same. The distance between adjacent pixels of diagonal direction is √2 times of that in horizontal and vertical direction. In hexagonal pixel structure, the distance from middle pixel to all the neighboring pixels is same. The centroid of middle pixel is at the same distance from the centroids of six adjacent pixels [6].

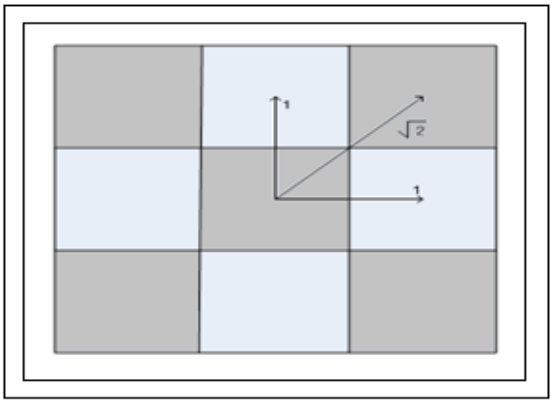

FIG. 9 DISTANCE IN SQUARE PIXEL STRUCTURE

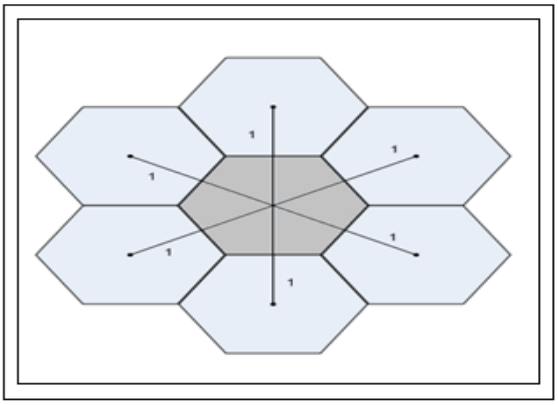

FIG. 10 DISTANCE IN HEXAGONAL PIXEL STRUCTURE

3. *HIGHER SYMMETRY*

The square pixel exhibits 4-fold symmetry whereas hexagonal pixel exhibits 6-fold symmetry. Many morphological operations are developed by Serra which are been widely used in image processing [7]. He studied this for different grids and found that hexagon grid has higher symmetry. The reflection symmetry of both square and hexagonal pixel is shown below:

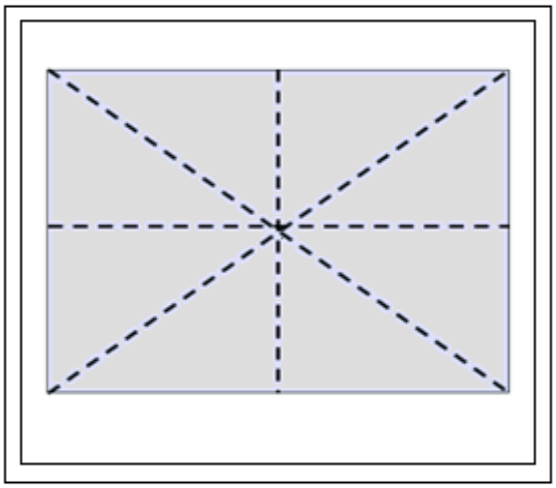

FIG. 11 SQUARE SYMMETRY

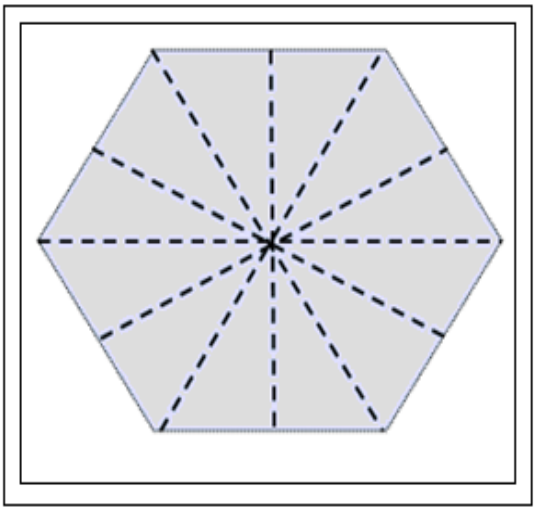

FIG. 12 HEXAGONAL SYMMETRY

4. GREATER ANGULAR RESOLUTION

In square pixel structure, adjacent pixels are separated by 90 degree which cause jaggiest in curved images. In hexagonal pixel structure, adjacent pixels are separated by 60 degree. Human eye have special visual preference of seeing lines which are at oblique angle because of its resemblance to that of the photoreceptors in human eye [8]. This results in better angular resolution.

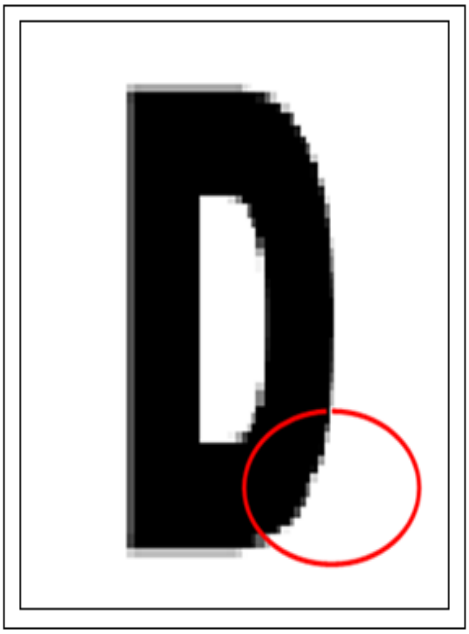

FIG. 13 ANGULAR RESOLUTION IN SQUARE PIXEL

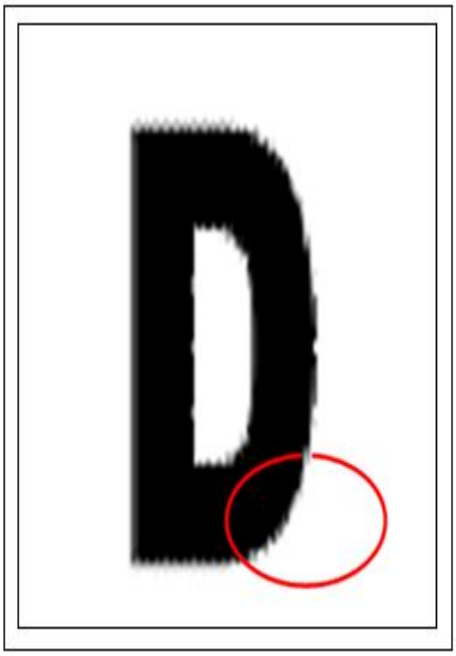

FIG. 14 ANGULAR RESOLUTION IN HEXAGONAL PIXEL

5. ALIASING EFFECT

In square pixel structure, aliasing effect is more due to insufficient sampling rate. In hexagonal pixel structure, the number of pixels required to sample and represent image is less, this provides sufficient samples which results in less aliasing. Mersereau found that signals in Fourier space require only 13.5% lesser samples to represent the same

image in hexagon grid as compared to square grid [9]. Middleton concluded that fewer samples are required to reconstruct wave number limited signal in hexagon lattice [10].

6. QUANTIZATION ERROR

For image processing operations, quantization is compulsory because of limited capability of sensors to represent real world scenes. Quantization error is important factor to analyze the merits of configuration of different types of sensors. Kamgar-parsi developed expressions for the estimation of quantization error in hexagon spatial sampling [11]-[13]. It is found that for a given resolution capability of sensors, hexagon sampling gives smaller quantization error.

7. STOARAGE SPACE and COMPUTATION

Vitulli investigated the sampling efficiency with the use of hexagonal grid and concluded the same as mersereau explained. He also concluded that hexagon grid provides sampling with fewer amount of pixels for wide spectra of signal [14]. Hexagonal pixel structure is tightly and closely packed to each other which require less storage space and less computation time.

IV. CONCLUSION

The use of hexagonal pixel based images has gained much attention in recent years in image architecture. From above explanations, it is clear that there is improvement and better visualization with hexagonal sampling. Since there is lack of hardware for capturing hexagonal based images, spiral addressing gives very good approach for simulating hexagon image processing. 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.

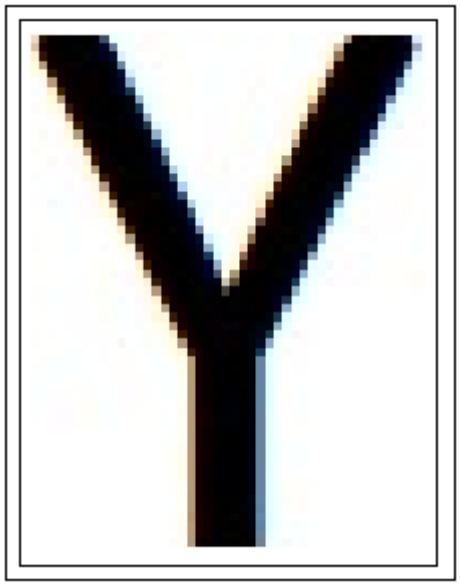

FIG. 15 SQUARE IMAGE

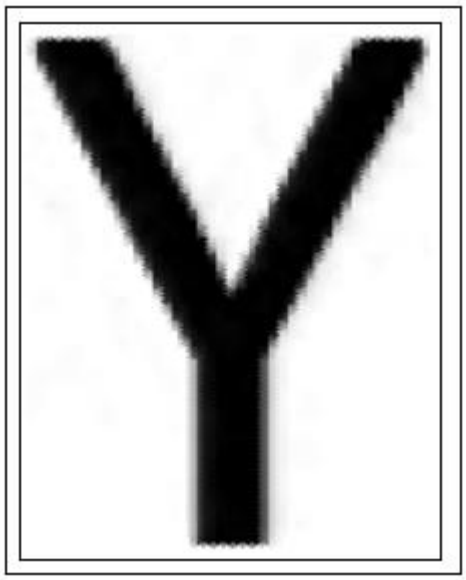

FIG. 16 HEXAGONAL IMAGE

REFERENCES

[1]. J. Foley, A. Van Dam and J. Hughes, *Computer Graphics, Principles and Practice*, second ed., Addison Wesley, Sydney 1990.

[2]. Mersereau, R.M., *The processing of Hexagonally Sampled Two-Dimensional Signals*, Proceedings of the IEEE, Vol. 67, pp. 930-949, 1979.

[3]. Curcio, C.A., et al., *Human Photoreceptor Topography*, Journal of Comparative Neurology, Vol. 292, pp. 497-523, 1990.

[4]. Hirsch, J. and Miller, W.H., *Does Cone Positional Disorder Limit Resolution?*, Journal of the Optical Society of America: Optics, Image Science, and Vision, Vol. 4, pp. 1481-1492, 1987.

[5]. Mollon, J.D. and Bowmaker, J.K., *The Spatial Arrangement of Cones in the Primate Fovea*, Nature, Vol. 360, pp. 677-679, 1992.

[6]. Yabushita, A. and K. Ogawa, *Image reconstruction with a hexagonal grid*, Nuclear Science Symposium Conference Record, IEEE, 2002.

[7]. Serra, J., Introduction *to Mathematical Morphology*, Computer Vision, Graphics, and Image Processing, Vol. 35, pp. 283-305, 1986.

[8]. Xiangjian He and Wenjing Jia , *Hexagonal structure for Intelligence Vision*, Computer Vision Research Group, University of Technology, Sydney, Australia.

[9]. Mersereau, R.M., *The processing of Hexagonally Sampled Two-Dimensional Signals*, Proceedings of the IEEE, Vol. 67, 930-949, 1979.

[10]. Lee Middleton and Jayanthi Sivaswamy, *Hexagon Image Processing – A Practical Approach*, Springer-Verlag London Limited 2005.

[11]. Kamgar-Parsi, B. and Sander, W.A., *Quantization error in spatial sampling: comparison between square and hexagonal pixels*, Proceedings of IEEE Computer Society Conference on Computer Vision and Pattern Recognition, CVPR, pp. 604-611, 1989.

[12]. Kamgar-Parsi, B., *Evaluation of quantization error in computer vision*, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 11(9), pp. 929-940, 1989.

[13]. Kamgar-Parsi, B., *Quantization error in hexagonal sensory configurations*, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 14(6), pp. 665-671, 1992.

[14]. Vitulli, R., et al., *Aliasing effects mitigation by optimized sampling grids and impact on image acquisition chains*, IEEE International Geosciences and Remote Sensing Symposium, IGARSS, Vol. 2, pp. 979-981, 2002.