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Hexagonal Image Representation Techniques: A Review

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Abstract— Image processing is becoming very popular and user friendly because of its usage in a number of applications like digital imaging, photography, video frames etc. By now, almost each modern display device has pixels in square form. The basic reason behind this is that the data is acquired and stored only in the form of square pixels. Since the scenario is changing very rapidly with usage of advanced technologies that made the systems more natural like the resemblance of the captured scenes with the human visual system. Also, just because of the natural occurrence motivated researchers to hypothecate the concept of hexagonal pixels. A hexagonal coordinate system maps the pixel information of an image in the form of hexagonal pixels instead of square one. This paper deals with a review of existing hexagonal pixels image representation techniques.

Keywords- *Hexagonal grid, Hexagonal addressing scheme, Image processing.*

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I. INTRODUCTION

Today is the world of digital imaging. In this digital work, the credibility of the various complex tasks goes to computer graphics technology. In this challenging world, the great challenges faced by the academicians and scientists are the representations of pixels. This is because, of the various parameters related to pixels representations are: scaling, storage, size of image, time of processing etc. These parameters give a choice to researchers to work with different pixel representation techniques. In almost each and every application the pixel representation is in the form of square pixels. But, literature reveals that other pixel tessellation techniques also occur in nature i. e. triangular pixel tessellation and hexagonal pixel tessellation. Due to the various advantages of hexagonal pixel tessellation over other pixels tessellations, the researchers have contributed their efforts for image representations using hexagonal pixels. This paper deals with a review of various techniques used for representation of hexagonal pixel images.

The complete paper is organized as follows: section I deals with the introduction to pixels representation for image processing. Section II describes the various hexagonal pixel image representation techniques. Finally, Section III provides the final conclusion and discussions along with the results obtained after conversion of square pixel image to a hexagonal pixel image.

I. Hexagonal pixel image representation techniques

The image resampling techniques are used to convert a square coordinate system image into hexagonal coordinate system image. Despite of the numerous advantages described earlier for hexagonal pixels structure, the image processing based on hexagonal pixels is not in major use for image processing tasks. The main reason is that currently the non availability of hexagonal-pixels structure based device for capturing and display of digital images. So, the reproduction of hexagonal samples images on available square display devices is now a serious issue that affects the advanced research on hexagonal pixel structure in the field of computer vision, graphics and image understanding. Fortunately, a number of researches (1-5) have contributed their work to reproduce hexagonal pixels structure using square pixels structure. The use of these techniques allows every researcher for taking the advantages of hexagonal pixels structure in computer graphics and computer vision for image understanding. The conversion techniques are as follows:

A. Mimic hexagonal pixels using square pixels structure

He and Staunton (3, 4) has proposed that a hexagonal pixels structure data may be designed by delaying sampling by half a pixel width on alternate TV scan lines in horizontal direction. In this scheme, the pixels are in square pixels structure. In other words, horizontal and vertical directions have identical sampling intervals. The implementation procedure is as follows:

Calculate the midpoint between two adjacent pixels by simple linear interpolation technique. i.e. mid = (left + right) / 2). Discard the left and right value, keeping only the mid values as given by equation.

$$S_{new}(x, 2y) = S_{old}(x, 2y) \quad (1)$$

$$S_{new}(x, 2y + 1) = \frac{S_{old}(x, 2y + 1) + S_{old}(x + 1, 2y + 1)}{2} \quad (2)$$

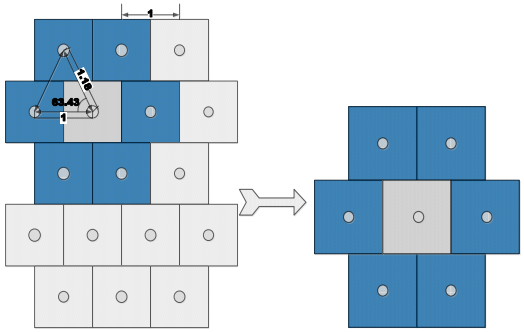

Figure 1: Mimic hexagonal pixel using half pixel shift method.

From the figure 1 shown above, it is understood that the above described structure presents a hexagonal pixels structure in a rectangular pixel shape, and it is observed that there is one center pixel and all the six neighbors of the center pixel form a circle. The centre of the circle is called as sampling point. The main benefits of this structure are that, the center pixel is equidistant from its nearest horizontal neighboring pixels. But neighboring diagonal pixels do not represent equidistance

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property and the angle subtended by two diagonal pixels is 63.43°. However, these hexagonal pixels don't preserve equidistance property, due to this reason; this technique has a loss in image resolution. If the two neighboring pixels have a vertical as well as horizontal distance of 1 unit, then the diagonal distance between two adjacent pixels will be √5/2 i.e. 1.18 approximately.

B. Pseudo hexagonal pixel

'Hyperpel' is the name that has been assigned to a hexagonal pixel. Pseudo hexagonal pixels are designed by the author Yuan (2) and the work was extended by Yabushita (1). In this simulation design; a scheme is proposed in which hexagonal pixel structure is produced using a number of square pixels structure. The conversion had been done in such a way that the density of square pixels was comparable with hexagonal pixels. That resulted in a loss in the screen resolution. The implementation of these two simulation schemes is shown as below:

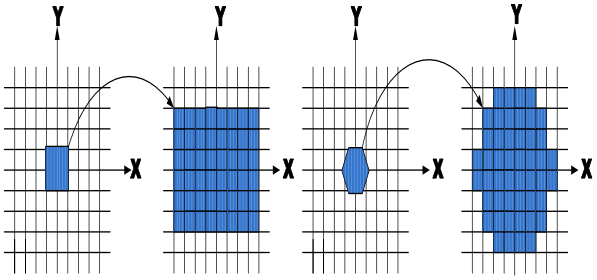

Figure 2: Simulated pixel structure: square simulation and pseudo hexagonal simulation (3).

C. Virtual hexagonal pixel

Another hexagonal structure mimicking scheme that came into picture was proposed by Wu (5) called as 'virtual hexagonal pixel'. This technique is different from the other methods in a way that there is no direct use of hexagonal pixels. The conversion is implemented during the processing part. All the techniques discussed above primarily convert the square pixel to hexagonal pixel and perform their tasks on it. But in this technique the virtual spiral architecture occurs only during processing of an image. It implies that processing of images is realized on those virtual hexagonal pixels. Finally, the processed data is converted back to square pixel for display. The major advantage of this technique is that it retains image resolution without any distortion. Also the disadvantage of this approach is that the computational cost of conversion between square and hexagonal pixels is high.

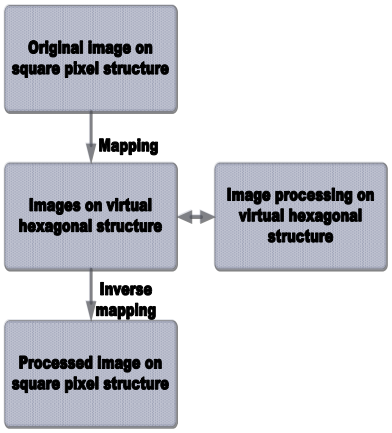

Figure 3: Virtual hexagonal method (6).

D. Spiral addressing scheme

Like the square pixels, the points in the hexagonal pixels cannot be addressed using Cartesian coordinates. The reason behind this is that the points in hexagonal pixel structure are not aligned in two orthogonal directions. It has observed that the hexagonal pixels cannot be addressed in rows and columns order as in the traditional rectangular structure. One-dimensional spiral addressing scheme will be used here for addressing hexagonal pixels. In this scheme each hexagonal pixel is assigned a unique base seven address. This can be achieved by initially applying to a collection of seven hexagonal pixels arranged as shown in figure 4. The addresses of these seven hexagonal pixels are assigned with base seven addresses i.e. 0, 1, 2, 3, 4, 5 and 6. It means that the address of center pixel is assigned as 0; and its six neighboring pixels have the address from 1-6 respectively. Similarly, the next address will be 10-16 and so on as shown in figure 5. Thus this addressing follows the path of spiral addressing scheme. Thus, through this scheme hexagonal pixels tile a complete plane without gaps and overlaps [8].

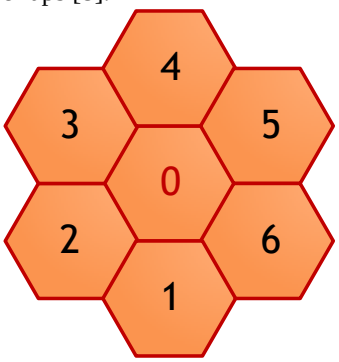

Figure 4: Addressing of seven hexagonal pixels.

Figure 5 details the addressing of a bunch of 7^2 = 49 square pixels. Because of the equidistant property of hexagonal pixels, all center pixels are equidistant from their six neighboring pixels.

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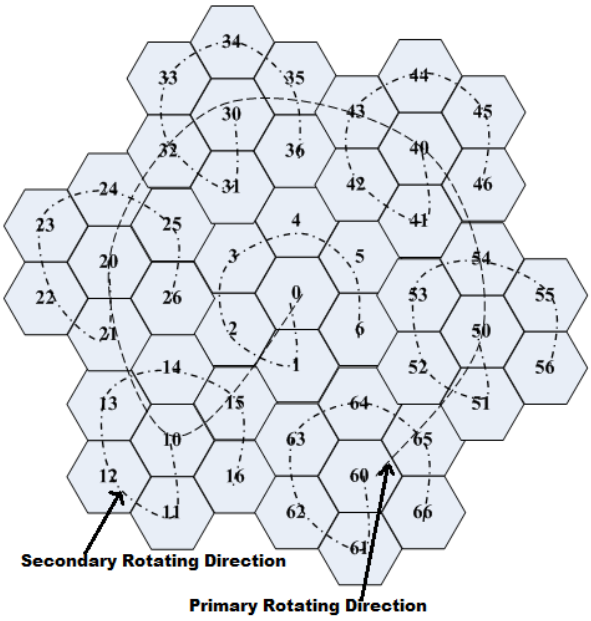
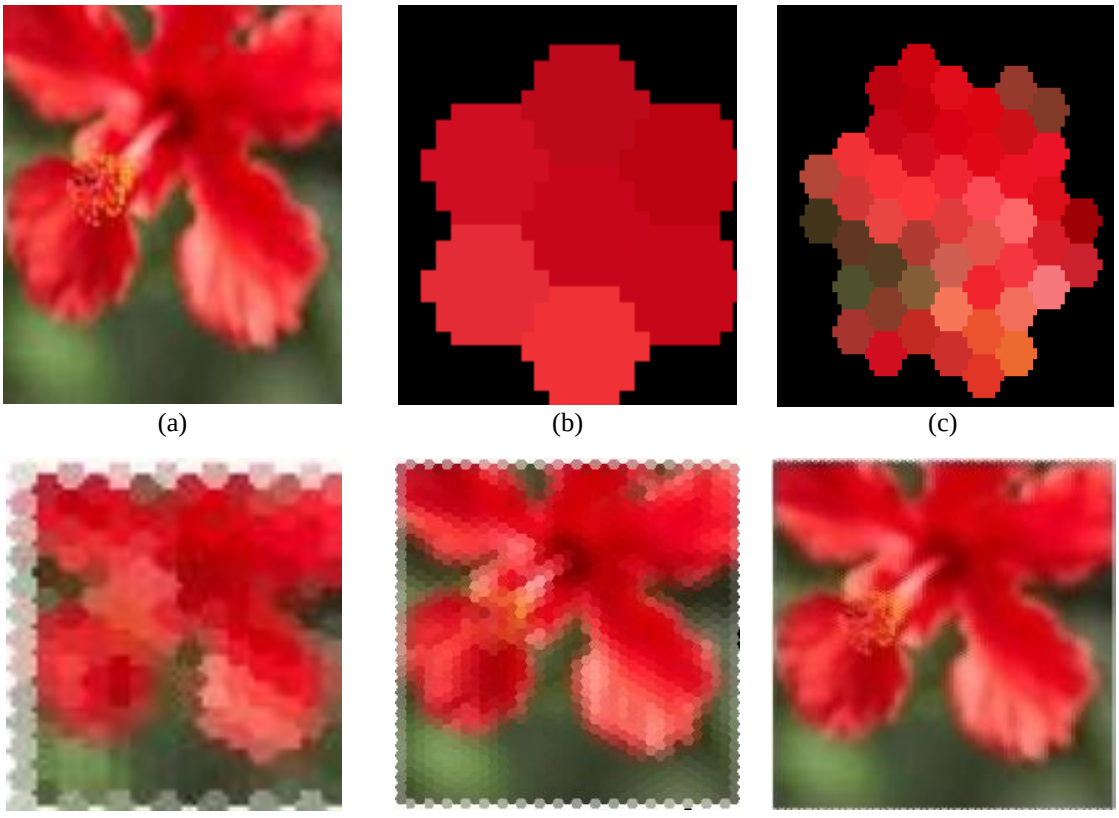


Figure 5: Spiral addressing scheme (7).

IV. Conclusion & Results

This paper, reviewed four hexagonal conversion schemes and it has been observed that spiral addressing scheme does not change image resolution and image distortion and also provides greater angular resolution, consistent connectivity, higher symmetry and lesser quantization error with lesser aliasing effects. Figure 6 represents the results of image constructed through this framework (Spiral addressing scheme) for level 1, 2, 3, 4, 5. The original image is of the size of 128 X 128. The level 1 is designed using 7 hexagonal pixels; the level 2 is designed using 7^2 hexagonal pixels; the level 3 is designed using 7^3 hexagonal pixels and similarly level 4 and level 5 are designed using 7^4 and 7^5 hexagonal pixels respectively.



(a) (b) (c)

(d) (e) (f)

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Figure 6: (a) original image of square pixels, (b) Cluster of 7 hexagonal pixels image, (c) 7^2 hexagonal pixels image, (d) Cluster of 7^3 hexagonal pixels image, (e) Cluster of 7^4 hexagonal pixels image, (f) Cluster of 7^5 hexagonal pixels image [9].

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