

Study on Hexagonal Grid in Image Processing Fayas Asharindavida, Nisar Hundewale, Sultan Aljahdali
Taif University, Saudi Arabia* ABSTRACT Image processing is very important in several applications and have been using in them very efficiently. Normally we use a rectangular grid for the processing of images.[23] Wu, Q., He, X., and Hintz, T., "Virtual Spiral Architecture". Proceedings of the International Conference on Parallel and Distributed Processing Techniques and Applications, 1, 399-405 (2004). [24] Luczak, E. and Rosenfeld, A., "Distance on a Hexagonal Grid".[3] Frederic Chazal, David Cohen-Steiner, Andre Lieutier, "A sampling theory for compact sets in Euclidean space",. Proceedings of the 22nd annual symposium on Computational geometry, ACM (2006). [4] Rajan, E.G., Sanjay, T., and Pramod Sankar, K., "Hexagonal Pixel Grid Modeling and Processing of Digital Images Using CLAP Algorithms", International Conference on Systemics, Cybernetics and Informatics, February 12-15, (2004).[5] Staunton, Richard C. and Storey Neil, "A comparison between square and hexagonal sampling methods for pipeline image processing", Proc.SPIE, Vol. 1194, 142-151 (1989). [6] Lee Middleton and Jayanthi Sivaswamy, [Hexagonal Image Processing – A Practical Approach], Springer-Verlag London Limited (2005). [7] 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, 2, 979-981 (2002). One of the resampling techniques to obtain hexagonal grid is to suppress alternate rows and columns from the square * Email : fayas.a@tu.edu.sa , nisar@computer.org , aljahdali@tu.edu.sa , Website: cit.tu.edu.sa sampled image 4 as shown in the figure, Fig 1 and the image processing operations can be performed on the resampled hexagonal image.[10] Kamgar-Parsi, B., "Quantization error in hexagonal sensory configurations", IEEE Transactions on Pattern Analysis and Machine Intelligence, 14(6), 665-671 (1992). [11] Gonzalez, R.C. and Woods, R.E., [Digital image processing], Prentice Hall, New Jersey, (2002). [12] Deutsch, E.S., "Thinning algorithms on rectangular, hexagonal, and triangular arrays", Communications of the ACM, 15(9), 827-837 (1972).[21] Middleton, L. and Sivaswamy, J., "Framework for practical hexagonal-image processing", Journal of Electronic Imaging, 11(1), 104-114 (2002). [22] Qiang Wu, Xiangjian He, Tom Hintz, "Image segmentation on spiral architecture", Proceedings of the Pan-Sydney area workshop on Visual information processing , Australian Computer Society Inc, 11(1), (2001). Researchers introduced various addressing schemes and coordinate systems to implement the hexagonal grid at least theoretically. Sampling lattice is one aspect of the sensing methodology used in computer vision.[8] 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, 604-611 (1989). [9] Kamgar-Parsi, B., "Evaluation of quantization error in computer vision", IEEE Transactions on Pattern Analysis and Machine Intelligence, 11(9) 929-940 (1989).[13] Staunton, R.C., "An analysis of hexagonal thinning algorithms and skeletal shape representation", Pattern recognition, 1131-1146, (1996). [14] Mylopoulos, J.P. and Pavlidis, T., "On the topological properties of quantized spaces I- the notion of dimension". (a) Hexagonal image structure with indices (b) Balanced ternary addition Generalized Balanced Ternary System is modified by Middleton and Sivaswamy [6] and proposed the single index system for addressing pixels for hexagonal image processing as in Fig 6(b) and 6 (c).[17] Serra, J., " Introduction to Mathematical Morphology,"

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Fig 3 (a) Hexagonal structure using half pixel shift
 Fig 3 (b) Rectangular pixels on a hexagonal sampling grid

Staunton [3] proposed a new approach in which the central pixel which is the sampling point has all its neighboring pixels arranged in a circular shape as in Fig 3 (b).Mersereau [2] 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.

7 REFERENCES

[1] Golay, M., "Hexagonal parallel pattern transformation", IEEE Transactions on computers, 18(8), 733–740 (1969). [2] Mersereau, R.M., "The processing of Hexagonally Sampled Two-Dimensional Signals", Proceedings of the IEEE, 67,930–949 (1979).

Thus we can represent a hexagonal grid of pixels on the existing rectangular screens for modeling and processing purpose, which is more suitable for computer vision modeling.

Fig 1 (a) Rectangular sampling (b) Hexagonal sub sampling

Another resampling method was proposed by Staunton [5] which is to shift the alternate rows of pixels in the image by a half pixel distance.

3.7 Higher Symmetry

Many morphological operations are developed by Serra [17] and are been widely used in Image processing .He studied the same on different grids and identified the fact that hexagonal grid has higher symmetry and simple operations.Each point is represented as a unique ordered pair of the vectors and can easily converted to and from Cartesian coordinate system. Fig 4 2–axes coordinate system for hexagonal structure

5.2.Spiral architecture

consists of this addressing scheme and two operations defined on it which are spiral addition and spiral multiplication which corresponds to translation of the image and rotation of the image respectively.

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Once sampling lattice is digitized into hexagons, various image processing operations can be performed on these sub-sampled images.Implementation of Hexagonal grid can be done in various methods including the spiral addressing scheme.

Image processing, Hexagonal grid, Hexagonal addressing scheme, spiral addressing scheme

1 INTRODUCTION

Researchers have been studying the feasibility of introducing the hexagonal grid in the area of 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 .Lack of capturing and display devices in hexagonal grid makes it impossible to attain the benefits of hexagonal grid.

4.1 Mimic Hexagonal Pixels Using Square Pixels

In this, He [16] proposed a method by delaying the alternate TV lines by half a pixel width.

3 FEATURES OF HEXAGONAL SAMPLING SCHEME

Digitization is one of the hardest tasks which scientists were worried about in image processing.Vitulli also found out that using the hexagonal grid, wider spectra of signal can be sampled without aliasing with fewer amounts of samples.

2 (a) (b) Fig 2 Distance in square grid and hexagonal grid

In hexagonal grid, there is only one consistent connectivity and each pixel has

six neighboring pixels.

4. HEXAGONAL IMAGE REPRESENTATION

Even after getting all the advantages of the hexagonal grid it has not been used widely in image processing.

6. CONCLUDING REMARKS

From the above discussions and explanations it is clear that there will be improvement while processing with hexagonal sampling. Out of the many advantages for the hexagonal structure in image processing, the primary one is its resemblance with the arrangement of photoreceptors in the human eyes. Hexagonal grid is also a pixel tessellation scheme which is efficient than any other schemes. But all of the methods are simulations only and thus we cannot achieve the real advantages of the hexagonal grid. Many resampling techniques were proposed like brick wall, quincunx sampling, least squares approximation of splines, etc.

3. Vitulli⁷ also investigated the sampling efficiency using hexagonal grid and concluded that it's the same as Meersereau explained in his work.

Greater Angular Resolution

For representing curved images hexagonal grid is efficient. Adjacent pixels in hexagonal grid are separated by sixty degree instead of ninety degree in the existing one. Yabushita¹⁹ took this idea and extended to create a pseudo hexagonal structure which was also made from square pixels in the aspect ratio of 12:14.

4.3 Mimic Hexagonal Structure

In this, one hexagonal pixel means four square pixels and the equivalent grey level value is the average of these pixels.

2.5 HEXAGONAL STRUCTURE ADDRESSING

Till we have discussed about representing and mimicking the hexagonal pixels to simulate the hexagonal grid.

5.1 2-Axes coordinate addressing scheme

Luczak and Rosenfield²⁴, proposed the two axes oblique coordinate system (Fig 4) to address hexagonal structure.

5.2 Single Indexing System

Another addressing scheme was introduced by Middleton and Sivaswamy⁶ which is called as Spiral Architecture (Fig 6 (a)) based on single dimensional addressing system. 'L' is the number of levels, 'M' is the number of rows in the image, 'N' is the number of columns in the image. The addressing scheme using spiral addressing scheme have many advantages over other addressing schemes as well as from square image processing. Since there is no dedicated hardware available for hexagonal based image capturing and display, conversion has to be done from square to hexagonal image before hexagonal image processing. There is no inconsistency in pixel connectivity and thus angular resolution is higher in this arrangement. Applying hexagonal grid in image processing is very advantageous and easy for mimicking human visual system. Normally digital images are mapped on square lattice and here we are changing the square lattice to hexagonal lattice for the hexagonal image processing. The following section describes the various features of hexagonal sampling scheme. Due to this limitation researchers are trying to mimic the hexagonal grid on rectangular grid itself.

3.1 Regular Tessellation schemes

There are only three tessellations available to tile a plane which is regular and the samples do not overlap among each other and with its gaps. All other tessellation schemes will either be inconsistent in the neighborhood connectivity or will become gaps or overlaps among the samples. The square tessellation is the commonly used one and it uses the Cartesian coordinate system for all operations and thus it is simple.

3.6.3/2.4.2. If ' ?