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Preparation for Using Non-Traditional Grids in Digital Image Processing

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Abstract

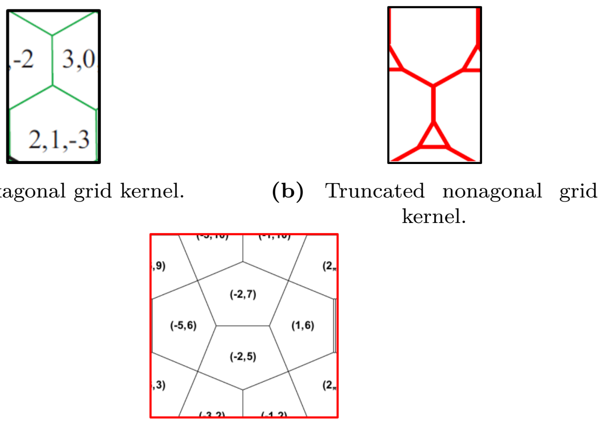
For decades, the square grid based on the Cartesian coordinate system has been the dominant structure in digital imaging and display. This structure is extremely convenient from a hardware perspective (memory addressing, sensor manufacturing), but it raises several topological and geometric problems during image processing [3, 4]. One of the most critical points is the handling of edges: while vertical and horizontal lines are continuous, completely diagonal edges experience information gaps due to pixel connections. This phenomenon results from the inhomogeneous neighborhood relations of the square grid, where the distance of immediate neighbors alternates between $d = 1$ (side neighbor) and $d = \sqrt{2}$ (diagonal neighbor). This inconsistency extends to the violation of the digital version of the Jordan Curve Theorem, creating a topological paradox for which one of the most known solutions is that a curve can only be considered 'closed' if the neighborhood definitions for the object and its background are inconsistently applied (e.g., 8-connectivity for the curve and 4-connectivity for the background, or *vice versa*). To address this problem without using special methods, it is suitable to use non-traditional grids.

In our study, we investigate the application possibilities of non-traditional grids, specifically those exhibiting hexagonal or triangular symmetry alongside traditional square lattices. While modern imaging devices produce high-resolution data, most image processing algorithms still operate on downsampled, lower-resolution versions to maintain efficiency. Our software framework resamples images onto al-

ternative grid structures at reduced resolutions, allowing us to emulate existing algorithmic workflows while averting the topological paradoxes inherent in the traditional square grids [2]. The final goal of this framework is to convert images on traditional square grid into various non-traditional grids to identify the most optimal grid for any given task.

During the research, we developed a conversion procedure that allows us to transform existing, conventional images into a predefined non-traditional grid. During the process, we first perform a geometric alignment, where we determine the ideal positions of the grid tile located above the source image. The sampling is implemented using kernels as visible on Figure 1. The algorithm examines the pixels enclosed by the given tile, and then determines the color code of the non-conventional cell by simply averaging them. With this method, we save the discrete image data into a topologically more stable grid.

The primary challenge to the practical application of non-traditional grids has been the complexity of their coordinate systems. Due to the inherent symmetry of these lattices (e.g., hexagonal or triangular), the traditional (x, y) integer-based indexing cannot be directly applied [1]. Consequently, spatial properties and distance relations differ from those typical of Cartesian coordinates, requiring specialized indexing methods to handle the data effectively.



(a) Hexagonal grid kernel.

(b) Truncated nonagonal grid kernel.

(c) Cairo grid kernel.

Figure 1. Different proposed grids in their kernel form.

Once the coordinate system is set, the integration of existing image processing algorithms becomes easy, and our possibilities are significantly expanded. Since the hexagonal grid naturally handles curvatures and direction-independent convolutions, it is possible to develop specific image processing methods that are free from the distortions experienced in traditional environments. The results obtained in this way enable more accurate edge detection and more efficient pattern recognition in the field of machine vision.

References

[1] I. Her: *Geometric transformations on the hexagonal grid*, IEEE Transactions on Image Processing 4.9 (1995), pp. 1213–1222, doi: 10.1109/83.413166.

[2] L. Middleton, J. Sivaswamy: *Processing images on square and hexagonal grids - a comparison*, in: Hexagonal Image Processing: A Practical Approach, London: Springer London, 2005, pp. 151–196, isbn: 978-1-84628-203-4, doi: 10.1007/1-84628-203-9_7, url: https://doi.org/10.1007/1-84628-203-9_7.

[3] B. Nagy: *Non-traditional 2D Grids in Combinatorial Imaging – Advances and Challenges*, in: Combinatorial Image Analysis, ed. by R. P. Barneva, V. E. Brimkov, G. Nordo, Cham: Springer International Publishing, 2023, pp. 3–27, isbn: 978-3-031-23612-9, doi: 10.1007/978-3-031-23612-9_1.

[4] A. Rosenfeld: *Connectivity in Digital Pictures*, J. ACM 17.1 (Jan. 1970), pp. 146–160, issn: 0004-5411, doi: 10.1145/321556.321570, url: https://doi.org/10.1145/321556.321570.