ABSTRACT

About 97% receptive field of the neurons is very closely described as 2D Gabor wavelet and it is mostly suitable for vision system modeling [8]. Immense work is available on texture information, especially for rectangular structures [37-40]. However, there is a little work in recognizing minute details in an image by either interpolation or enhancement.

Hexagons have many advantages namely six fold symmetry, well behaved connectivity, improved angular resolution, storage savings, computational speed, and circular 7-pel shape. In the tessellations with Hexagons, if \( v \) is spatial domain lattice, then frequency domain lattice or reciprocal lattice \( \tilde{v} \) is obtained as \( \tilde{v} = 2\pi(v^{-1})^T \). The basis vectors in the two domains are seen to be mutually orthogonal, which is due to the fact that the Fourier transform is an orthogonal projection. In the past years, there had been many attempts in representing hexagons in the regular square lattice or in a Spiral Addressing Scheme (SAS) [13-34]. Regular geometry is only kept in the case of SAS, however processing such pseudo lattices gave rise to better results compared with square lattices.

This research work started with implementation of above mentioned hexagonal pseudo lattices and later entered on a real hexagonal lattice through the Hex - spline process described by D. Van De Ville et al. [45]. Hex-spline process is a structure where regular hexagon can be represented and it is basically used for interpolation. Filtering the images was attempted by Gabor kernels in hexagonal domain in different orientations, on this type of structure. As the orthogonal directions of the Gabor filter in the three directions \( (0^\circ, 60^\circ, 120^\circ) \) are converged between three adjacent pixels, it was considered important to filter out the images in these directions.

A low pass filter and high pass filter may be used to enhance surface information and edge information respectively. When the kernels are placed on image pixel locations and add, it is not only giving just image enhancement, but also facilitates interpolation. This is because, as the sigma values in a Gabor
filter reduce, the Gaussian envelope covers only a part of a wave of the modulating sinusoids, to render a low-pass characteristic to the filter. While the low-pass component is predominant, the edge enhancement part is still present in the three orthogonal directions as additional nonlinearity in the kernel. Hence, three orientations Hex-Gabor filter was designed and the resultant kernel was obtained by adding the responses at $0^0$, $60^0$, and $120^0$. There are controversies about selection of sigma parameters for Gabor filter, since processing is always relevant to the existing pixels being modified as in the case of enhancement. It has been proved that this controversy does not exist in this method, as only a unique value of sigma would suit for Hex-Gabor filtering. The results showed that only an optimum value of sigma ($2/\pi$) made a visually error-free image. It was also noted that minor corrections are required at the receding end of the kernel, by windowing. It is clearly evident that $\sigma$ values have to be kept same in all directions, however only the specific value could yield a good result. In scattered images like X-rays, the contribution to intra-pixel information is not very obvious, and hence this was attempted. Different sigma values enhanced different depth information in such images.

Probing into the significance of the Hex-Gabor kernel parameter $\sigma=2/\pi$, it was found that at $2/\pi$, the kernel was isotropic, unipolar but nonlinear. This enabled filtering that would enhance the image edges and would retain smooth information in any regular lattice. The resulting kernel was also used in rectangular lattice and we could obtain same results as that has been achieved with hexagonal image processing. This shows the importance of considering components in orthogonal directions. It also shows that if this is considered, even a shift from regular hexagonal lattice of the retinal elements could be suitably compensated. The results also show how finer details are visualized by this sigma selection by the eye. For sigma values more than $2/\pi$, the kernel was not unipolar, however it works suitable for edge detection as a pre processing step to a limiting value of sigma up to $4/\pi$. This research work also includes the Field Programmable Gate Array (FPGA) implementation of Cellular Logic Array Processing (CLAP) algorithm based edge detection, thinning and reconstruction over a hexagonal lattice as original contributions.