CHAPTER 6

CONCLUSION

Image signals are quite often subjected to contamination by undesirable noise components, when they are processed by an electronic system or transmitted over a communication channel. This contamination may take on many forms. For example, the electronics in the imaging system may introduce additive noise having uniform and Gaussian statistics; impulse noise might be caused in a camera by a faulty sensor; additive Gaussian noise and impulse noise may corrupt the images transmitted over noisy channels. Moreover, edges as well as fine details are the essential features of images, as they contain important information and visual perception is heavily based on these features. In this thesis, some nonlinear filtering strategies, based on order-statistics, have been introduced for suppressing signal-independent additive white i.i.d. noise and/or impulse noise without damaging the essential features of images.

Simple nonlinear highpass filter algorithms for detecting edges in one- and two-dimensional signals have been introduced. A high level structure for VLSI implementation of the one-dimensional highpass filter has been developed. VLSI simulation results obtained using the one-dimensional highpass filter have been presented. The two-dimensional highpass filter, based on the one-dimensional highpass filter, has been derived for detecting and preserving image edges. A novel feature of the two-dimensional highpass filter is that it is sensitive to the orientation of an image edge. That is, the filter can detect and preserve the edges as horizontal, vertical, left diagonal and right diagonal edges. The two-dimensional highpass filter is compared to the
commonly used edge detectors in terms of computational requirements and is found to be less complex. The performance of the filter has also been evaluated qualitatively by applying it to a test image in both noisy and noise-free environments. The proposed filter is seen to preserve edge structures quite well with much less background noise.

Four new nonlinear image-filtering schemes, referred to as New Filter I, New Filter II, New Filter III and New Filter IV, have been proposed. The two-dimensional highpass filter algorithm forms the basis for these new filters. New Filter I is effective in suppressing Gaussian noise. New Filter II is robust against impulse noise and reduces Gaussian noise sufficiently. New Filter III yields adequate noise attenuation in the presence of noise having uniform probability density function. New Filter IV exhibits good noise filtering characteristics for uniform and impulse noise. The proposed filters are designed to have good edge preserving characteristics. The filters are evaluated for their performance in terms of two objective quality measures, namely, the image enhancement factor obtained at different noise levels and the MSE/pixel produced by windows of various sizes. Furthermore, the results of filtering of noisy images have been presented for subjective evaluation. From all these results, it has been observed that the proposed filters perform better than typical conventional filters in eliminating noise without destroying edge information.

A new class of midpoint-type nonlinear filters, useful for recovering the images from the noisy data, has also been developed. To begin with, the Alpha Trimmed Midpoint (ATMP) filter has been introduced. The ATMP filter sorts out the samples, removes extreme high and low endpoints and then performs midpoint filtering. Next, the Adaptive Alpha Trimmed Midpoint (AATMP) filter has been described. The filter performs in an adaptive manner
using edge information. It operates as an ATMP filter in the homogeneous regions and works as a median filter (with the same window size as that of the ATMP filter) in the neighbourhood of edges. The Modified Adaptive Alpha Trimmed Midpoint (MAATMP) filter, presented in the end, is similar to the AATMP filter except that it operates as a median filter of window size 3x3 in the neighbourhood of edges and sharp corners, irrespective of the size of the window of the ATMP filter. Two test images, corrupted by different levels of uniform and impulse noise, are used for evaluating these filters. The ATMP, AATMP and MAATMP filters are found to be robust against impulse noise and effective in attenuating uniform noise. The subjective results of filtering show that the proposed adaptive filters have good edge preservation properties because they continuously adapt to the image characteristics. Further, the MAATMP filter is seen to perform better than the AATMP filter in retaining fine details, while the noise removal properties of the latter are superior to those of the former in the neighbourhood of edges and sharp corners.

The preservation of image features and the elimination of noise are usually two contradictory aspects in image processing. For example, median filters blur image corners leading to the loss of fine details with larger windows or yield insufficient noise reduction with smaller windows. Fine detail preservation is an important requirement in signal and image processing applications. A technique for improving the performance of median smoothers at the corners, characterized by low order polynomials, has been introduced. The proposed scheme, called as the combination smoother, consists of a 3-point median smoother and a larger median smoother of desired window length in parallel; besides, it has a combiner for appropriately combining the outputs of the median filters. The combiner algorithm combines the detail preserving characteristics of the 3-point smoother and the better noise filtering
characteristics of the larger smoother. The combination smoother is evaluated using quantitative (image enhancement factor) and qualitative (subjective visual criterion) measures by applying it to a test image corrupted by different levels of impulse and/or non-impulse noise. The results obtained indicate that the combination smoother outperforms the 3-point smoother in noise suppression and the larger smoother in preserving image details.

All the proposed filters are suitable for VLSI implementation. However, the proposed filtering techniques require further research in developing suitable architectures for reliable single-chip filters useful for high-speed real-time image processing applications. The usefulness of the proposed techniques for speech, music, seismic and sonar signal processing can also be investigated.

Even though a remarkable development has been achieved in order-statistic filtering, there are many open questions and research problems of considerable interest. For example, the root structures of weighted median filters are not yet fully understood. Once this is achieved, the design of optimal weighted median filtering under structural constraints will become possible. Adaptive nonlinear order-statistic filters, which can suppress noise without damaging the geometric structures of signals, continue to be a topic of fruitful research.

In conclusion, this thesis has presented some new nonlinear robust filtering techniques and demonstrated their usefulness in image filtering. The filters are shown to be effective in suppressing additive i.i.d. uniform, Gaussian and/or impulse noise, while preserving edges and fine details. The proposed filters are suitable for VLSI implementation and further research work needs to be carried out in this direction.