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Abstract

Image denoising has always been one of the standard problems of the image analysis and processing community. It is motivated by itself or by some practical application such as preprocessing for e.g. remote sensing applications, medical image diagnosis; the goal is to reduce noise. The successful image denoising algorithms are mainly based on transforms. Recent research in transform based image denoising has stressed on the wavelet transform due to its superior performance over other transforms such as Fourier, Karhunen-Loeve transform, Discrete cosine transform. It is applied to image processing successfully for last two decades. It has been shown in several papers that wavelet-based methods arise naturally for image denoising.

The first part of this thesis is for additive noise. The proposed algorithms use local adaptivity based on static of neighboring pixels in wavelet domain. These statistics consist of energy and variance in different scales that capture certain statistical regularities of natural images. The existing methods are limited because they make at least one of the following three assumptions: i) the wavelet coefficients are independent; ii) the signal component of the wavelet coefficient distribution follows a specified parametric model; and iii) the wavelet representation of all signal of interest has same level of sparsity. We propose two methods namely locally adaptive energy (LAE) and locally adaptive variance (LAV), based on locally adaptivity that addresses each of these issues. The algorithm uses Discrete Wavelet Transform (DWT) to extract information about sharp features in multiresolution images and applies shrinkage function adapting the local statistics of the image. The shrinkage function depends on standard deviation or

energy of neighboring pixels, whereas in standard wavelet methods, the empirical wavelet coefficients shrink pixel by pixel, on the basis of their individual magnitude. The algorithms use very few and intuitive parameter. The parameters are first chosen by heuristic approach then it is optimized. The cost function used for the optimization process is to minimize the mean square error.

To asses the performance of our methods, we have compared it with several standard wavelet-based denoising algorithms on a number of benchmark natural images. A very important aspect of all the denoising methods and proposed methods is to the accurate estimation of the noise level. Therefore this topic is treated in detail to review noise estimation methods. Two methods are implemented and assessed thoroughly, one in spatial domain and other in wavelet domain.

The second part of this thesis is for multiplicative noise. The noise is reduced to detect geographical features in synthetic aperture radar (SAR). SAR images are corrupted by speckle noise which is multiplicative in nature. Existence of this noise may hide details and thus, reduce resolution of these images. The speckle degrades the quality of the image and makes difficult to interpret, analysis and classification of the SAR images. This noise is signal dependent and different from additive noise used in natural images. In this thesis, speckle is reduced by multiscale analysis in wavelet domain. The SAR image is first despeckled then the features are detected by wavelet filter.

The third part is devoted to image enhancement method using image regularity. Enhancement often includes a denoising and a deblurring or sharpening step. It has been shown that the Holder regularity is decreased with additive white Gaussian noise. The regularity is estimated by wavelet coefficient in different scale then it is increased as perceived by a human observer.

The thesis contains denoising algorithms for two types of noises: additive noise and multiplicative noise. Two methods are proposed for additive noise. The geographical feature detection method is proposed for SAR images which are affected by multiplicative noise. The enhancement algorithm is applied for denoising when the type of noise is unknown.

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LIST OF SYMBOLS

f	True Image
f'	Noisy image
$E[.]$	expected value
$\hat{f}$	Estimated image
η	Holder exponent
σ_n^2	Noise variance (contaminated)
$\hat{\sigma}_n^2$	Estimated noise variance
$\phi(.)$	Scaling function
$\phi_{j,k}(.)$	Translated and dilated Scaling function
$\psi(.)$	Wavelet function
$\psi_{j,k}(.)$	Translated and dilated wavelet function
ξ_B	Homogeneity measure of block B
$\hat{m}_k$	Expected kth moment of data
λ	Threshold value
λ_{univ}	Universal threshold value
λ_{soft} , λ_{hard}	Soft and hard threshold value
Δ	Sobel operator
A	Approximate subband image
D	Diagonal subband image
G	Gradient amplitude

g	Gradient amplitude
H	Horizontal subband image
h	Histogram
J	Largest level of decomposition
j	Decomposition level
L	Number of gray levels
m_k	k^{th} moment of data
M_k	Normalized moment of data
$m_{l,n}$	Holder exponents
N	Noise
R	Number of gray levels
t	Time or unitless index
$T(.,.)$	Threshold operator
V	Vertical subband image
$Var\{.\}$	Variance operator
V_j	Approximate subspace at scale j
W_j	Detail subspace at scale j

LIST OF ABBREVIATIONS

1-D	One dimensional signal
2-D	Two dimensional signal
ABE	Amplitude-scale-invariant Bayes estimator
AR	Autoregressive
ASIC	Application-specific integrated circuits
ATR	Automatic target recognition
AWGN	Additive white Gaussian Noise
bpp	bits per pixel
CDF	Cumulative distribution function
COI	Cone of influence
CWT	Continuous wavelet transform
dB	Decibels
db2	Daubechies Wavelet basis 2
DCT	Discrete cosine transform
DWT	Discrete wavelet transform
EM	Expectation Maximization
ENL	Equivalent number of looks
FIR	Finite impulse response
GGD	Generalized Gaussian Distribution
GMM	Gaussian mixture model
GSM	Gaussian Scale mixture
HMC	Hidden Markov Chain

HMT	Hidden Markov Tree
ICA	Independent Component Analysis
iid	Independent, identically distributed
IPSNR	Incremental peak signal to noise ratio
IV	Image variance
LMMSE	Linear minimum mean square error
LMS	Least mean square
LSI	Linear shift invariant
MAD	Mean absolute difference
MAE	Mean absolute error
MAP	Maximum A Posteriori
mips	Millions instructions per second
MNSS	Multiplicatively non-stationary speckle
MRA	Multiresolution analysis
MRF	Markov random field
MSE	Mean squared error
MSS	Multiplicatively stationary speckle model
pdf	Probability distribution function
PSNR	Peak signal to noise ratio
RAM	Random access memory
ROM	Read only memory
SURE	Stein's unbiased risk estimator
SWT	Stationary wavelet transform

Sym4	Symlet wavelet basis 4
UDWT	Undecimated discrete wavelet transform
WCAE	Worst case absolute error
WP	Wavelet Packets
WSS	Wide-Sense stationary
WT	Wavelet Transform
WTMM	Wavelet transform modulus maxima

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