NEW APPROACHES TO COLOR IMAGE RESTORATION AND ZOOMING OF COMPRESSED VIDEO

Submitted in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

by

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Abstract

In this thesis we address two image processing problems, namely restoration and zooming. We refer to restoration as a process of removing degradation from observed, degraded images and zooming as generating missing data from the observed sparse data. Thus, removal of blur and noise fall into the restoration category. For image restoration, we consider color images, which are degraded by interchannel blurring. For zooming we consider zooming still image and video clip.

The first of the problems addressed in this thesis is image restoration. Restoration - removal of blur and noise - is an *inverse problem*. Most inverse problems are *ill-posed* in nature, and are tackled by *regularization* an energy function. In general, energy functions associated with restoration problems will be non-convex, and could have several local minima and non-unique global minima. These aspects make image processing tasks interesting and challenging. More so, in the case of color images, as we do not know the exact nature of color processing by the human eye. Here, we assume that a color image is degraded by both inter and intra channel blurring. That is, blurring on one color plane (say red) depends not only on the pixel values of the plane in question (red, in this example), but also on other color planes (i.e., green and blue). Amount of interchannel blurring is unknown, making the proposed model partially *blind problem*. We propose to model the image as a Markov Random Field (MRF) and color image restoration is cast as a maximum *a posteriori* (MAP) problem. We use line fields in the MRF and use simulated annealing for energy minimization. We propose a First-order Interchannel Interaction (FOII) model for the restoration scheme, and mention the advantages and limitations of the proposed scheme. Comparing the proposed model with the one that does not consider interchannel degradation, we see that the proposed FOII model performs better, both numerically and visually, even when interchannel blurring is unknown.

The second problem addressed in this thesis is still image zooming. To zoom a given image, we have to *estimate* missing pixels from an observed low-resolution image. We propose to estimate these missing pixels in the wavelet domain. Wavelet decomposition

has the following property: if a coefficient at a finer level is known, we can estimate wavelet coefficients at a coarser level. We assume that converse of this is possible: If we know wavelet coefficients at a coarser level, we can estimate coefficients at a finer level. Along with this assumption, we make use of the property: at sharp edges, wavelet coefficients decay exponentially across the scales. Using these two properties, we propose a simple method to estimate wavelet coefficients at a finer level. We mention the advantages and limitations of the proposed method. Results show that for a general class of images, the proposed method gives very good results, both visually and numerically.

The third problem addressed in this thesis is video zooming. Novelty of the proposed method is that zooming is done in the compressed domain and not in the spatial domain. We propose to interpolate the motion vectors in the compressed domain. It is assumed that motion vectors for video are transform coded, and, decoded values of these are available. We extrapolate these motion vectors to locate corresponding blocks in the zoomed video frame. Use of motion vectors make the proposed technique independent of the method of compression. This fact is justified by considering the motion vectors obtained from Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). We also consider a video stream compressed using Multiresolution Motion Estimation (MRME) technique to show that the proposed method performs satisfactorily. We further extend the scheme to temporal interpolation that is, estimating missing video frames. We use motion vector as a cue to estimate the missing frames.

***Key words* :** Image Restoration, Image Zooming, Video Zooming, Markov Random Field, Simulated Annealing, Wavelets, Multiresolution Analysis, Motion Vector, Image Compression, Video Compression, Temporal Interpolation

List of Acronyms

CWT	:	Continuous-time Wavelet Transform
DCT	:	Discrete-time Cosine Transform
DFT	:	Discrete-time Fourier Transform
DWT	:	Discrete-time Wavelet Transform
EZW	:	Embedded Zerotree Wavelet
FOII	:	First-order Interchannel Interaction
FIR	:	Finite Impulse Response (filter)
GD	:	Gibbs Distribution
KL	:	Karhunen-Lóve
LIP	:	List of Insignificant Pixels
LIS	:	List of Insignificant Set
LSP	:	List of Significant Pixels
MAP	:	Maximum *a posteriori*
MMSE	:	Minimum Mean Square Estimation
MRA	:	Multi-Resolution Analysis
MRF	:	Markov Random Field
MRME	:	Multi-Resolution Motion Estimation
MSAD	:	Multiresolution Sum of Absolute Differences
NI	:	Non-Interaction
PR-QMF	:	Perfect Reconstruction Quadrature Mirror Filter
PSF	:	Point Spread Function
PSNR	:	Peak Signal to Noise Ratio
QMF	:	Quadrature Mirror Filter
RGB	:	Red-Green-Blue (color/color coordinate)
RLC	:	Run Length Coding
SA	:	Simulated Annealing
SAD	:	Sum of Absolute Difference
SAQ	:	Successive Approximation Quantization
SNR	:	Signal to Noise Ratio
SPIHT	:	Set Partition in Hierarchical Trees
STFT	:	Short Time Fourier Transform
SVD	:	Singular Value decomposition

List of Symbols

$y(.,.)$	:	observed -degraded image pixel at location (,)
$x(.,.)$	:	original image pixel at location (,)
$h(.,.)$	:	Point Spread Function
$n(.,.)$	:	noise value at location (,)
X, Y	:	Lexicographically ordered vectors of x and y respectively
$\mathbf{H}$	:	PSF matrix formed from $h(,)$
L	:	A square lattice
η	:	neighborhood system
M	:	Size of a lattice
S	:	Subset
c	:	clique
$\mathcal{C}$	:	set of all cliques
$P[X = x]$	:	Probability
$P[. \mid .]$	:	Conditional Probability
Z	:	Normalizing function
T	:	Temperature
$U()$	:	*a priori* energy function
$U_p()$	:	*a posteriori* energy function
$\mathbf{R}$	:	Auto-correlation matrix
$\psi()$	:	prototype mother wavelet function
$L^2(\mathbb{R})$	:	space of square integrable functions
$\Psi()$	:	Fourier Transform of $\psi()$
$\mathbf{Z}$	:	Set of integers
$f()$	:	function
$\phi()$	:	Scaling function
V_j	:	j^{th} subspace in MRA
W_m	:	orthogonal complement of V_j in V_{j-1}
$\oplus$	:	Direct sum
V_{j-1}	=	$V_j \oplus W_m$
E	:	Expectation operator
$\mathbf{D}$	:	Decimation matrix
$\lfloor . \rfloor$	:	floor operator
$D_{(.)}(,)$	:	Decay parameter
$\mathbf{\Phi}$	:	KLT matrix
Ω	:	Search area

${}^{k}b_p^g$	:	k^{th} macro block of p^{th} video frame of size $g \times g$
${}^{k}B_p^g$	:	Discrete orthogonal Transform of ${}^{k}b_p^g$
$\mathcal{O}(,)$	:	set of ofspring nodes
$\mathcal{D}(,)$	:	set of all descendants
$\mathcal{L}(i,j)$	=	$\mathcal{O}(i,j) - \mathcal{D}(i,j)$
$\mathcal{H}$	:	coordinates of all spatial orientation tree roots
$S_n(,)$	:	Function indicating presence of non-zero motion vector in a set of coordinates $(,)$
θ	:	Threshold
v, h	:	Vertical and horizontal line fields
V_c	:	Clique potential
κ	:	Sample space
μ	:	Smoothness in MRF energy function
γ	:	Penalty term in MRF energy function
w	:	Motion vector
$\mathbf{0}$	:	null matrix

Acknowledgments

I take this opportunity to express my gratitudes to all those who helped me directly or indirectly to reach this goal. In no way the list is complete. If some names are missed out, it is purely oversight.

First, I would like to express my thanks to Prof. U. B. Desai. Without his constant encouragement, support and guidance, I could not have reached this point. He gave me all the freedom for me to work, thereby making the work enjoyable. He was a source of inspiration to pursue my work-his way of working has inspired me a lot. Thank you, Professor. I was lucky to have an active association with Prof. Subhasis Chaudhuri. Discussions with him have helped me a lot during my tenure at IIT Bombay. Words fail to express my feelings towards these two Professors, the gratitude can only be felt. I only hope all the people will have such a nice group to work with.

I would like to place on records the help and encouragement rendered by Dr. Ashok Rao. His proper directions led me to SPANN lab, IIT. Without him, I would have ended up "barking at a wrong tree"

Most of the faculty of electrical engineering department, IIT Bombay helped and encouraged me during my stay at IIT. Prof. V.M. Gadre, Prof. Manjunath, Prof. Karandikar, Prof. S. D. Agashe, Prof. H. Narayanan, Dr. Sumantra Dutta Roy have all lent me a helping hand all-through. I recall memories of (late) Prof. K. Shankar who inspired me a lot with his morale boosting words. Prof. K. V. V. Murthy and family, Prof. Sheshu (civil dept.) and family have left a marking in my mind with their kind gestures.

I was lucky to have nice people at SJCE, who encouraged and motivated me during the research program. I remember with gratitude the support rendered by Prof. A. Prakashan, Prof. M.L. Dwarakanath, Dr. C. R. Venugopal, C. R. Nataraj, Sebi Kumar and *all* my colleagues at SJCE, for *all* their help (this includes sharing my load during my absence!). Without their kind gesture it could not have been possible for me to reach this stage. I would like to thank Aprameya Swarup for his patience reading of my thesis and suggesting necessary corrections.

I was fortunate to have a good academic minded friends. Their presence, discussions with them, and their expertise, their sense of humor etc., are remembered (sometimes with a pinch of salt). I cherish my association with (a few names are mentioned. There are more): Dr. K. Sunil Kumar, Nilesh Hiremath, Dr. Rajagopalan, Dr. Jayashree, H.L Shashidhara, Vinayadatt Kohir, Milind Patil, Onkar Dabeer, Vinayak Wagle, Dr. Sunil Suvyia, Kusha Shetty, , Murali Krishna, Sudarshan Shindhe, B.N Chaudhari, Tushar Agarwal, Dr. Srinivasulu Gupta Dr. T. S. Sunil. Recent entries to the bandwagon are Anant Malewar, Akshay Mishra, M.V. Joshi M.A. Zaveri, and Sibi Raj. Dr. Manivasakan and Deepak Nayak did critical proof reading of the thesis and gave valuable suggestions; I thank them for the trouble taken by them. H.R Prabhakar and family, Dr. Udaya Kumar and family were of great help at the home front. Dr. Deepu Rajan kept me company in most part of my research work. Discussion with him have helped me a lot in carrying out this work. Dear friends, your absence will be felt.

I was fortunate to work in the Signal Processing and Artificial Neural Network Lab (SPANN Lab). This well equipped lab (machines, book and subject experts) molded me towards research activities. I thank SPANN Lab. and all the people involved in administering and maintaining it. I miss the overall IIT environment, which motivated me to work harder. I only wish we have more such campuses and more such labs. GNU project, Linux OS and LaTeXwere god given gifts. Without these work would not have been as enjoyable. IIT Kannada Balaga is one place which helped me come out of gloom and nurtured my interest in extra-circular activities. It was really nice to get associated with such an organization and the people associated with it. In particular, I thank Prof. Srirangarajan (Mech) and Prof Shrinath (Aerospace).

Without the QIP program, it would not have been possible to pursue my doctoral degree. I thank AICTE for the QIP program. My parent college Sri Jayachamarejendra (S. J.) College of Engineering was kind enough to grant me leave to pursue my doctoral studies. I thank all the people who were responsible for sponsoring me to PhD program.

My in-laws Smt. Sunanda and Sri M.N Chalgeri have helped me and my family in all my endevours. Their help at family front was one of the key factors in completing this work. My thanks to them. Mr. Mohan Waydande of campus school taught me to play flute, thereby, helping me to realize my childhood dream. Thanks to him for making my dream come true.

There were a good number of kids (too many to name here) in the campus, who have helped me to come out of depression, by their mere presence. Their shining eyes...cheerful smile...innocent mannerism... I miss them all. Their presence was felt more as I was staying away from my family. Story of *Kabuliwallah?*

I would like to thank Smt. Shashikala Nair, Chandrakant Kadam "Chandu" of SPANN Lab for all their help. I also would like to remember *all* my teachers (again too many to name here). Right from my primary school till now. Many of them have inspired me and guided me in proper direction. *guravennamaha*

My sincere thanks to some of the people who have inspired me (both academically and non-academically) - Prof. K.S Deshpande and family Dharwad, with a special mention to Smt. Kusum Deshpande. Dr. V.D. Chafekar, Gadag, who taught me practical electronics. Dr. C. B. Murthy and family of Mysore, for all their help. The families, known as A to Z family of Mysore, have lent their helping hand at my home front, while I was away. I remember with gratitude their kind gesture. Thanks to my sister Dr. Varsha Mokhasi, who has kept the competitive spirit among all the time.

A relay team should have all best runners, but the first and the last should be *the* best. Similarly, *the best* people have figured at the beginning of my acknowledgment. I would like to end with the other *the best* group. My last acknowledgments are to all the three of my family members: My son Shreenidhi, who had to postpone his arrival into this world as his *appa* was away, my daughter Deepika, who had to spend four of her eight years without her *appa*, and my wife Malini. She managed home front well in my absence (*very* well, in fact). Thank you Malini

Dedicated

To My Father

ನನ್ನೀ ಜೀವನ ಸಮುದ್ರ ಯಾನಕೆ
ಚಿರ ಧೃವ ತಾರೆಯು ನೀನು

मेरे जीवन का समुद्र यान को
चिर ध्रुव तारा हो तुम

For the voyage of my life,
you are the pole star

my Mother

ಮನೆಯೆ ಮೊದಲ ಪಾಠಶಾಲೆ
ಜನನಿ ತಾನೆ ಮೊದಲ ಗುರುವು

घर हि पेहला पाठशाला जननि ही पेहला गुरू

Home is the first school,
mother is the First teacher