

**NOVEL APPROACHES FOR SUPER RESOLUTION OF
INTENSITY/RANGE IMAGE USING SPARSE
REPRESENTATION**

A THESIS

submitted by

SRIMANTA MANDAL

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of

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“Whenever we attain a higher vision, the lower vision disappears of itself.”

– Swami Vivekananda

To My Parents

Smt. Madhumita Mandal and Sri. Sibaram Mandal

My Sister

Shampa Mandal

Declaration

I hereby declare that the entire work embodied in this thesis is the result of investigations carried out by me in the **School of Computing and Electrical Engineering**, Indian Institute of Technology Mandi, under the supervision of **Dr. Anil Kumar Sao**, and that it has not been submitted elsewhere for any degree or diploma. In keeping with the general practice, due acknowledgements have been made wherever the work described is based on finding of other investigators.

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THESIS CERTIFICATE

This is to certify that the thesis titled **NOVEL APPROACHES FOR SUPER RESOLUTION OF INTENSITY/RANGE IMAGE USING SPARSE REPRESENTATION**, submitted by **Srimanta Mandal**, to the Indian Institute of Technology, Mandi, for the award of the degree of **DOCTOR OF PHILOSOPHY**, is a bonafide record of the research work done by him under my supervision. The contents of this thesis, in full or in parts, have not been submitted to any other institute or university for the award of any degree or diploma.

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Dr. Anil Kumar Sao
(Guide)

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ABSTRACT

Keywords: *Super resolution, sparse representation, edge preservation, depth map, range image, point cloud completion, sampling, dictionary, clustering, edge orientation, principal component analysis, image details, image pyramid, additive noise, singular value decomposition, non-local similarity, distant face recognition, edginess.*

Super resolution (SR) aims to restore an approximated version of the original high resolution (HR) scene from the given low resolution (LR) image. As there could be different possibilities of HR scenes that can produce the same LR image, the process of SR is ill-posed in nature. In order to achieve an HR image, the inverse problem has to be regularized with prior knowledge about the HR image. Sparsity inducing norm can be used to address the regularization issue, but it can not take care about preserving edges, which are perceptually important in any image. To mitigate with this concern, we propose an edge preserving constraint that preserves the edges of the input image in the SR result in the framework of sparse representation. This constraint is useful to improve the quality of the result of SR for intensity images, and is further investigated for range image (or depth map). It is found that the edge preserving SR is well suited for this modality. This is because the resolution enhancement of range images is primarily gauged in terms of retention of object shape and inter-object discontinuities. Further, we address the issues of higher up-sampling as well as non-uniform up-sampling requirement for depth map. The non-uniform up-sampling requirement is caused by the sparse point cloud that is generated from structure from motion part in the pipeline of depth estimation. The sparse point cloud can be interpreted as a non-uniformly sampled LR depth map. To up-sample the non-uniformly sampled LR depth map, we generalize the SR framework using a mask operator. Here, the missing depths at HR grid is filled using the dictionary of exemplars in sparse domain.

Dictionary plays an important role in the sparsity based SR. Often, the dictionary is learned using either structural information (dominant edge orientation) or statistical information (mean of intensity values) of image patches. The complimentary nature of both kind of information has not been explored, and an approach is proposed to address the same using example patches. The example patches are first clustered based on their dominant edge

orientation to generate structurally similar clusters, which may vary statistically. Hence, the structurally similar clusters are further divided using K-means clustering to generate clusters that consist of structurally as well as statistically similar patches. This kind of clustering strategy can produce dictionaries that can represent the target patch appropriately. Availability of good HR example image patches are very important to learn the dictionaries. If the example patches are unavailable, one has to explore the information available in the given LR image. Thus, we construct image pyramid by up/down-sampling the given LR image, and patches from the pyramids can be used to learn dictionary. Further, we choose the image patch details for SR, as it contains perceptually significant information. Here, image patch details is computed by subtracting the patch from the non-local mean of similar patches. If the given LR image is contaminated by noise, considering patch detail for SR will emphasize the noise also. To mitigate with this issue, we derive few parameters from the given LR image that reflects the strength of noise present in the image. These parameters are used: i) to derive a threshold that is employed in the sparse coding stage using iterative shrinkage/thresholding algorithm, and ii) to choose between the noise suppressing non-local mean component and the detail component. By enhancing suitable component using iterative thresholding algorithm, we are able to suppress noise while super-resolving a single image. Hence, we do not require the strength and type of additive noise in super-resolving a noisy LR image. Further, the problem of distant face recognition is addressed by an edge based SR strategy, where edge information is employed either explicitly by super-resolving edge related information or implicitly by preserving edges using a constraint in SR of gray scale face image.

Contents

Abstract	iv
List of Tables	xi
List of Figures	xiii
Abbreviations	xx
1 Introduction	1
1.1 Interpreting <i>Resolution</i>	3
1.2 The Objective of SR	4
1.3 Important Considerations of SR in Sparse Representation	7
1.4 Objective and Brief Description of the Work	9
1.5 Contributions of the Thesis	11
1.6 Organization of the Thesis	12
2 Background	14
2.1 Single Image SR	15
2.2 Addressing Ill-posed Problem by Regularization	17
2.3 Sparse Representation Framework	18
2.4 Sparsity Inducing Norms	20
2.5 Employing l_0 Norm	22
2.6 Approximation	23
2.6.1 Greedy Methods	23
2.6.2 Relaxation Methods	24
2.7 Summary	25

3	Edge Preserving Constraint	27
3.1	Introduction	27
3.2	Existing Techniques for Regularization	28
3.3	Motivation	30
3.4	Edge Preserving SR	31
3.5	Required Dictionary	32
3.6	Experimental Results	33
3.7	Summary	36
4	Generalizing SR to Restore Depth Map from Under-sampled Data	37
4.1	Introduction	37
4.2	Related Works	39
4.2.1	Related Works on Depth Map SR	40
4.2.2	Related Works on Point Cloud Completion	41
4.3	Proposed Approach of Depth Restoration	43
4.3.1	Problem Formulation:	43
4.3.2	Dictionary Learning:	45
4.3.3	Super-Resolution (SR)	46
4.3.3.1	Initialization	46
4.3.3.2	Dictionary Selection	46
4.3.3.3	Reconstructing Dense Depth Map with Edge Preservation	47
4.3.3.4	Pyramidal strategy	49
4.3.4	Point Cloud Completion (PCC)	49
4.3.4.1	Dictionary Selection	50
4.3.4.2	Effect of Missing Depths in Dictionary	51
4.3.4.3	Depth Restoration	52
4.3.5	PCC-SR	53
4.4	Experimental Results	55
4.4.1	Results of SR on Middlebury Dataset	55
4.4.1.1	Experimental Settings	55
4.4.1.2	Results in Absence of Noise ($\sigma_n = 0$)	56
4.4.1.3	Results in Presence of Noise ($\sigma_n = 5$)	59

4.4.2	Results of SR on Real Depth Map	60
4.4.3	Results of PCC	62
4.4.4	Results of PCC-SR	64
4.5	Summary	68
5	Employing Structural and Statistical Information to Learn Dictionaries	69
5.1	Introduction	69
5.2	Related Works	71
5.3	Proposed Approach	74
5.3.1	Learning Phase:	74
5.3.2	Reconstruction Phase:	79
5.3.3	Edge Preserving Constraint:	81
5.4	Experimental Validation	82
5.4.1	Experimental Geography:	82
5.4.2	Experimental Results without Noise:	84
5.4.3	Experimental Results with Noise:	88
5.4.4	Experiments with Different Up-sampling Factors and Datasets	92
5.4.5	Analyzing the Proposed Approach:	94
5.4.5.1	Parametric Analysis	96
5.4.5.2	Computational Analysis	100
5.5	Summary	101
6	Super Resolution from Single Image	103
6.1	Introduction	103
6.2	Related Works	104
6.2.1	Intensity Image SR	104
6.2.2	Range Image SR	105
6.3	Proposed Approach	106
6.3.1	Learning Dictionary:	107
6.3.2	HR Image Reconstruction:	108
6.4	Experimental Results	111
6.4.1	SR Results of Intensity Images:	111
6.4.2	SR Results of Range Images:	115

6.5	Summary	118
7	Noise Adaptive Super-Resolution from Single Image	120
7.1	Introduction	120
7.2	Related Works	122
7.2.1	Related Works on Noise Level Estimation	122
7.2.2	Related Works on Intensity Image SR	123
7.2.3	Related Works on Range Image SR	124
7.3	Proposed Scheme of SR from Single Image	125
7.3.1	Estimation of Parameters Related to Noise	126
7.3.2	Restoring the Image	130
7.3.2.1	Adapting the Sparse Coefficient Vector Estimation Based on Noise-related Parameters	131
7.3.2.2	Choosing Between Image Detail and Non-local Mean Component	132
7.3.2.3	The Dictionary in Restoring an Image	134
7.3.2.4	Edge Preservation	137
7.3.3	Algorithm	138
7.4	Experimental Results	138
7.4.1	SR Results on Intensity Images	141
7.4.2	SR Results on Range Images	143
7.4.3	Further Evaluation and Discussion	149
7.4.3.1	Analysing Different Components of the Proposed SR	151
7.4.3.2	Comparison with Denoising+SR approaches	153
7.4.3.3	Results of BSD100 Dataset	154
7.5	Summary	154
8	Distant Face Recognition	157
8.1	Introduction	157
8.2	Related Works	159
8.3	SR in Edginess Domain	160
8.3.1	Learning Phase	161
8.3.2	Reconstruction Phase	162
8.4	SR in Gray Level Domain Using Edge Preserving Constraint	164

8.5	Face Recognition by WD Analysis	165
8.6	Experimental Results	168
8.6.1	Edginess Domain SR-FR	168
8.6.1.1	Extended Yale Face Database B	169
8.6.1.2	CUBiC Facepix Database	170
8.6.1.3	Discussion	171
8.6.2	Edge Preserving SR-FR in Gray Scale Domain	173
8.6.2.1	Discussion	175
8.6.2.2	Results Using SCface Dataset	177
8.7	Summary	178
9	Summary and Future Work	180
9.1	Summary	180
9.2	Future Work	181
	References	183
	List of Publications	198