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Single Image High Resolution Using L2-Regularization

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ABSTRACT

Research on single image super resolution, which consists of improving a high-resolution image from its blurred, decimated and noisy version. The purpose of this review paper is to provide the knowledge of image enhancement or image scaling up and estimating a high-resolution image from a low-resolution image.
Keywords: Single Image Super-Resolution, Sparse Optimization, Single Image Super-Resolution, Deconvolution, Decimation

I. INTRODUCTION

SINGLE image super-resolution (SR), also known as image scaling up or image enhancement, aims at estimating a high-resolution (HR) image from a low-resolution (LR) observed image [1]. This resolution enhancement problem is still an ongoing research problem with applications in various fields, such as remote sensing [2], video surveillance [3], hyper spectral [4], microwave [5] or medical imaging [6].

The general approach considers the low resolution images as resulting from resampling of a high resolution image. The goal is then to recover the high resolution image which when resampled based on the input images and the imaging model will produce the low resolution observed images. Thus the accuracy of imaging model is vital for super resolution and an incorrect modelling, say of motion, can actually degrade the image further.

The goal of Super-Resolution (SR) methods is to recover a high resolution image from one or more low resolution input images. Methods for SR can be broadly classified into two families of methods: (i) The classical multi-image super-resolution, and (ii) Example-Based super-resolution. In the classical multi-image SR (e.g., to name just a few) a set of low-resolution images of the same scene are taken. Each low resolution image imposes a set of linear constraints on the unknown high resolution intensity values. If enough low-resolution images are available, then the set of equations becomes determined and can be solved to recover the high-resolution image. Practically, however, this approach is numerically limited only to small increases in resolution (by factors smaller than 2).

The methods dedicated to single image SR can be classified into three categories [7]. The first category includes the interpolation based algorithms such as nearest neighbour interpolation, bicubic interpolation or adaptive interpolation techniques. Despite their simplicity and easy implementation, it is well-known that these algorithms generally over-smooth the high frequency details. The second type of methods considers learning-based (or example-based) algorithms that learn the relations between LR and HR image patches from a given database. Note that the effectiveness of the learning-based algorithms highly depends on the training image database and these algorithms have generally a high computational complexity. Reconstruction based approaches that are considered in this paper belong to the third category of SR approaches. These approaches formulate the image SR as an reconstruction problem, either by incorporating priors in a Bayesian framework or by introducing regularizations into the ill-posed inverse problem.

II. RELATED WORK

T. Akgun, Y. Altunbasak, and R. M. Mersereau[4] have developed an efficient total variation minimization technique based on Split Bregman deconvolution that reduces image ringing while sharpening the image and preserving information content. The model was generalized to include upsampling of deconvolved images to a higher resolution grid. Furthermore, a proposed multiframe super-resolution method is presented that is robust to image noise and noise in the point spread function, and leads to additional improvements in spatial resolution.

J. Yang, J. Wright, T. S. Huang, and Y. Ma[7] presented a novel approach toward single image SR based upon sparse representations in terms of coupled dictionaries jointly trained from high- and low-resolution image patch pairs. The compatibilities among adjacent patches are enforced both locally and globally. Experimental results demonstrate the effectiveness of the sparsity as a prior for patch-based SR both for generic and face images. However, one of the most important questions for future investigation is to determine the optimal dictionary size for natural image patches in terms of SR tasks.

D. Glasner, S. Bagon, and M. Irani[8] proposed a unified framework for combining these two families of methods. We further show how this combined approach can be applied to obtain super resolution from as little as a single image (with no database or prior examples). Our approach is based on the observation that patches in a natural image tend to redundantly recur many times inside the image, both within the same scale, as well as across different scales. Recurrence of patches within the same image scale (at subpixel misalignments) gives rise to the classical super-resolution, whereas recurrence of patches across different scales of the same image gives rise to example-based super-resolution.

This paper aims at reducing the computational cost of these methods by proposing a new approach handling the decimation and blurring operators simultaneously by exploring their intrinsic properties in the frequency domain. However, the implementation of the matrix inversions proposed are less efficient than those proposed in this work. More precisely, this paper derives a closed-form expression of the solution associated with the L2-penalized least-squares SR problem, when the observed LR image is assumed to be a noisy, subsampled and blurred version of the HR image with a spatially invariant blur. This model, referred to as L2-L2 in what follows, underlies the restoration of an image contaminated by additive Gaussian noise and has been used intensively for the single image SR problem and the references mentioned above. The proposed solution is shown to be easily embeddable into an AL framework to handle non-Gaussian priors (i.e., non-L2 regularizations), which significantly lightens the computational burdens of several existing SR algorithms.

III. CONCLUSION

This paper reviews a variety of Super Resolution methods proposed and provides some insight into, and a summary of, our recent contributions to the general Super-Resolution problem. In the process, a detailed study of several very important aspects of Super-Resolution, often ignored in the literature, is presented. Specifically, we discuss improving a high resolution image from its blurred, decimated and noisy version. Image enhancement or image scaling up and estimating a high resolution image from a low resolution image.

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