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A Technique to Preserve Edge Information in Single Image Super Resolution

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Abstract

Goal of image super resolution is to enhance the size of an image without upsetting the inherited information. The quality of an enhanced image is conserved if the information around all kind of edges is preserved. The proposed novel approach potted the information around curvature edges and hard edges (abrupt transition in intensity) using Non Sub-Sampled Contourlet Transform (NSCT) based learning process. Furthermore the smoothness of smooth edges (gradual transition in intensity) is preserved by using soft edge smoothness prior as a regularizing parameter. The validity of the proposed approach is proven through simulation on several images.

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Keywords: Image Super Resolution, Non Sub Sampled Contourlet Transform, Soft edge smoothness prior

1. Introduction

Improvement of visual information for human interpretation is the principle requirement in satellite imaging, medical science and surveillance etc. The cameras used at the on-board circuit of satellite are of low resolution because of limitation of weight and cost. Image super resolution (SR) becomes an important task to interpret the information carried by an image captured by these low resolution cameras. More over high quality images have also a concern in High Definition Television (HDTV). Thus image super resolution is a process of achieving the best image quality through single low resolution (LR) image or multiple low resolution images of the same scene. The super resolution approach offers benefit of utilization of the existing available low resolution imaging system.

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Traditionally, image super resolution is classified as multi image super resolution and single image super resolution. Multi image SR technique uses multiple images of the same scene. The fusion of information from multiple LR images enables the reconstruction of high resolution (HR) image easier as compared to single LR image. This is because multiple LR images contain different information and this additional information can be exploited to obtain a HR image. Thus it remains a challenging task to reconstruct a HR image from single LR image with less amount of information at hand. This paper proposes a novel learning based approach for single image super resolution.

Image super resolution techniques can be mainly categorized as reconstruction based techniques and learning based techniques. The reconstruction based SR approach estimate a HR image from several LR images using a regularizing parameter called prior. If a prior probability distribution on the super resolution image is available then this information may be used to regularize the estimation. Numerous generic smoothness priors are proposed by previous researchers[1, 2, 3, 4] . These generic smoothness priors offer gradient field with lower magnitude which limits the magnification factor. An adaptive regularization method is fused with an adaptive sparse domain selection to obtain a HR image[5]. In learning based approach, the relationship between an LR image and its corresponding HR image is examined via a pair of LR and HR patches. The training data is used to predict the higher resolution image. Xie Qinlan et al. proposed an example based single image super resolution method that classifies the high frequency patches of low resolution image into different classes[6]. For the edge areas of the LR image, the routine example based image super resolution algorithm can be used to implement the local and fine super-resolution. For the flat regions of the LR image, only interpolation algorithm is used for super resolution. Local high frequency details are synthesize using both ordinary and residual training data sets[7]. To reconstruct high frequency details in estimated HR image, Jian Zhang et al.[8] had also used ordinary and residual high frequency dictionary learning via sparse representation method. Pulak Purkait et al.[9] had used sparse dictionary learning technique in to adaptively select a prior. Here, HR image is estimated from a LR image by selecting a prior locally using knowledge of local statistics of LR image. Coupled dictionary training method, proposed by Jianchao Yang et al. is optimized as bilevel optimization problem[10]. As a bilevel optimization the author achieved optimization that includes l_1-norm minimization problem.

The algorithm proposed by Dai S.[4] integrates bilateral filtering into back projection method. The basic idea is that pixels which are nearby both in space domain and feature domain are passed through smoothing process. This may tend to blur the edges and the details around the edges may be lost. The concept of nearest neighbor based algorithm is also used to reconstruct a HR image[11, 12]. The reconstruction results of these methods are blur since the number of neighbor ‘k’ is fixed which tends to scrub out the edge details. The proposed work prioritizes the information around the edges while performing super resolution.

The paper, presented here, proposed a novel approach in which NSCT based learning algorithm is framed together with edge smoothness prior to preserve edge information during super resolution process. The training dataset is constructed by performing three level pyramidal decomposition of each image in the training set. The benefit of directionality offered by NSCT is obtained through the two levels directional decomposition at each pyramidal level. However, learning is performed between two coarser NSCT levels of a low-resolution image and training dataset. During the learning process a LR patch may map to multiple HR patches which leads to appearance of unwanted outliers in the super resolved image. Therefore, in the proposed approach a robust Lorentzian error norm is used to remove these outliers in contrast to minimum absolute difference criterion (MAD)[13]. The directional Gabor filter bank increases quality of multi directional images at the cost of complexity[13]. Furthermore, Gabor filter is a directional filter and hence it is not able to retain smoothness of smooth edges. Hence the proposed method uses a edge smoothness prior to maintain smooth edges of the test image in the super resolution process. Finally an objective function formed by considering global data term (residual between original image and estimated HR image) and a prior term. This objective function is optimized via Iterative Back Projection (IBP) method. The proposed approach yields better results considering both smoother regions as well as texture regions. The obtained results are compared via both qualitatively and quantitatively with the state-of-the-art results. The quantitative comparisons are done on the same platform.

The rest of the paper is organized as follow: The basic of Non Sub Sampled Contourlet Transform (NSCT) is described in section 2. Section 3 depicts robust estimation of NSCT coefficients at the finer scale of unknown HR