Abstract

Patch based image restoration algorithms split a given degraded and/or noisy input image into the set of all possible overlapping patches, separately restore each of the patches, and finally compute the restored image by aggregating all the restored overlapping patches. Patch based algorithms exploit various types of patch priors to regularize the ill-posed inverse problems arising in commonly encountered image restoration problems. Patch priors encapsulate the essential characteristics typically exhibited by natural image patches. Recently, patch based image restoration algorithms exploiting Gaussian Mixture Models (GMMs) as a patch prior have been shown to produce impressive results in various image restoration problems. Recent works have also established the close connections between image restoration algorithms exploiting GMM priors, and the widely studied sparse representation or sparsity priors characterizing natural image patches. These works have proposed GMM analogues of several image restoration algorithms exploiting the sparsity prior. The GMM analogues generally offer superior performance, and are computationally faster when compared with the sparsity based algorithms.

In previous works, sparsity priors have also been shown to be good at jointly characterizing highly correlated natural image patches arising in certain image restoration problems such as Single Image Super Resolution (SISR) and color image restoration. In the case of SISR problem, a High Resolution (HR) patch and the corresponding Low Resolution (LR) patch are highly correlated as they differ only in scale. Similarly, the corresponding patches from different color channels, i.e., the patches around a common patch center, but from different color channels of a color image are generally observed to be highly correlated. In the literature, SISR algorithms exploiting sparsity prior for jointly characterizing the correlated HR-LR patch pairs, and color image restoration algorithms exploiting sparsity prior for jointly characterizing the corresponding patches from different color channels, have been demonstrated to achieve state of the art performance. However, joint characterization of correlated natural image patches using GMMs has not been previously studied in the literature. In this thesis, we investigate the potential of GMMs in jointly characterizing highly correlated natural image patches.

We propose GMM analogues of some of the previously studied image restoration algorithms exploiting sparsity prior for jointly characterizing natural image patches in SISR and color image restoration problems. We first propose a fast, example based SISR algorithm by exploiting a Joint GMM prior for characterizing the concatenated HR-LR patches. The

HR-LR patch correlations captured by the Joint GMM prior are exploited to estimate the unknown HR patch corresponding to an input LR patch. The proposed Joint GMM method can be interpreted as the GMM analogue of the sparsity based ScSR algorithm previously studied in literature. Next, we propose a SISR algorithm by using a GMM based regression method which can be seen as the GMM analogue of the recently proposed A+ algorithm delivering state of the art performance in patch based SISR. The GMM based regression method addresses the computational bottleneck of the learning method used for estimating the Joint GMM parameters from a given database of HR-LR patch pairs. The GMM based regression method significantly reduces the learning effort when compared with the Joint GMM method, and achieves superior performance in the case of large magnification factors. Finally, we propose color image restoration methods by exploiting a Joint Color Space GMM (JCS-GMM) prior that jointly characterizes the corresponding patches from different color channels of a color image. The JCS-GMM prior characterizes monochrome as well as color features, and captures the strong inter channel correlations typically observed in color images. We demonstrate the potential of the JCS-GMM prior by proposing JCS-GMM denoising and JCS-GMM demosaicking algorithms for addressing color image denoising and demosaicking. The proposed JCS-GMM method can be interpreted as the GMM analogue of the sparsity based Color-KSVD algorithm previously studied in literature. Our experiments demonstrate that the proposed algorithms achieve superior or competitive performance when compared with various state of the art SISR and color image restoration algorithms.