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Editorial

Image restoration and enhancement: Recent advances and applications

1. Introduction

Image restoration and enhancement is a classical research area in image processing. Previously, adaptive local and nonlocal approximations have been popular. Local approximations attempt to estimate the image content in a locally adaptive neighbourhood. Nonlocal methods exploit the self-similarity within the whole image without the constraint of locality. The former tends to be more efficient and the latter would produce better results. Recently, learning-based techniques adopting advances in machine learning and computer vision, such as sparse coding and dictionary learning, have attracted much more attention and been applied to image/video restoration and enhancement. These techniques can represent image contents better using learned dictionaries. In addition, some novel application areas, e.g., legacy photos and paintings, HD/3D displays, mobile and portable devices, and web-scale data, have prompted new research interests in image/video restoration and enhancement.

This special issue aims to promote research in image restoration and enhancement in a modern era by revisiting classical methods, proposing new techniques, and boosting novel applications. In total, we received 90 submissions from all around the world. The submissions cover a wide variety of areas including image denoising and despeckling, image reconstruction and super-resolution, image deblurring, demosaicing and dehazing, and other restoration and enhancement topics. After two rounds of vigorous review by at least two expert reviewers for each paper, we finally selected 33 high-quality articles to be included in this highly-popular special issue.

2. Overview of articles

We give an overview of all the included papers summarizing the contributions and novel aspects of each paper. All the articles are divided into 5 subsections roughly according to their areas, namely, Image Denoising, Image Reconstruction, Super-resolution, Despeckling, and Other Restoration and Enhancement.

2.1. Image denoising

The article entitled "A perceptual image completion approach based on a hierarchical optimization scheme" aims at introducing a novel efficient approach for high-quality and fast image restoration by combining both a greedy strategy and a global optimization strategy, based on a pyramidal representation of the image. A coarse version of the input image is first restored by exemplar-based method using a greedy strategy. From the low-resolution inpainted image, higher resolutions are interpolated and refined by a global optimization strategy. Experimental results on natural images demonstrate the effectiveness of the proposed method. Moreover, a comparison with some methods of the state-of-the-art confirms its superiority in terms of image quality and computational time.

The article entitled "A new non-local maximum likelihood estimation method for Rician noise reduction in Magnetic Resonance images using the Kolmogorov–Smirnov test" deals with denoising problem of MR images. Maximum Likelihood (ML) estimation methods were proved to be very effective in denoising MR images. Among the ML based methods, the recently proposed Non Local Maximum Likelihood (NLML) approach gained much attention. In the NLML method, the samples for the ML estimation of the true underlying intensity are selected in a non-local way based on the intensity similarity of the pixel neighbourhoods. This similarity is generally measured using the Euclidean distance. A drawback of this approach is the usage of a fixed sample size for the ML estimation resulting in over- or under-smoothing. This work proposed an NLML estimation method for denoising MR images in which the samples are selected in an adaptive and statistically supported way using the Kolmogorov–Smirnov (KS) similarity test. The method has been tested both on simulated and real data, showing its effectiveness.

The article entitled "Rough Set based Image Denoising for Brain MR Images" proposes a novel approach to explore self-similarity of an image for patch based image processing application. The proposed method explores image space globally for each given patch using Rough Set Theory (RST) in principled way. The similarity in the image space is explored according to predefined set of attribute(s) of the

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image. The selection strategy using RST has been applied for image denoising task to enhance capability of the underlying method. The paper has demonstrated the suitability of RST for similar patch selection applying it on two state-of-the-art methods and hence proposed a new algorithm in comparison to state-of-the-art methods efficient in terms of computational complexity. The applicability of denoising methods have shown on Medical image domain and evaluated quantitatively using various statistical measures. The performance of the proposed method found to comparable and satisfactory.

The article entitled "Natural Image Denoising Using Evolved Local Adaptive Filters" proposes a patch-based Evolved Local Adaptive (ELA) filter is proposed for natural image denoising. In the training process, a patch clustering is used and the Genetic Programming (GP) is applied afterwards for determining the optimal filter (linear or nonlinear in a tree structure) for each cluster. In the testing stage, the optimal filter trained beforehand by GP will be retrieved and employed on the input noisy patch. In addition, this adaptive scheme can be used for dierent noise models. Extensive experiments verify that the proposed method can compete with and outperform the state-of-the-art local denoising methods in the presence of Gaussian or salt-and-pepper noise. Additionally, the computational efficiency has been improved significantly because of the separation of the offline training and online testing processes.

The article entitled “Fast Blockwise SURE Shrinkage for Image Denoising” focuses on the general shrinkage estimation problem for image denoising under the additive white Gaussian noise model. Their work involves deriving the closed-form optimal blockwise Stein's unbiased risk estimator (SURE) shrinkage without additional optimizations. As such, the proposed method allows a better estimation of a clean image within a constant time complexity for an arbitrary image denoising method with available SURE. Simulation results reveal that this shrinkage solution is effective to a wide collection of image denoising methods.

The article entitled "A constrained optimization approach to combining multiple non-local means denoising estimates" addresses the problem of image denoising approaches that suppress noise while maintaining edge information. The non-local means (NLM) algorithm, a widely used edge-preserving patch-based method, is a highly effective technique but is sensitive to parameter tuning. This paper used a variational approach to combine multiple NLM estimates, seeking a solution that balances positivity constraints and gradient penalties against Stein's Unbiased Risk Estimate (SURE). This method greatly reduces parameter sensitivity and improves denoising performance vs. other NLM variants.

2.2. Image reconstruction

The article entitled "Adaptive Missing Texture Reconstruction Method Based on Kernel Cross-Modal Factor Analysis with a New Evaluation Criterion" presents an adaptive missing texture reconstruction method based on kernel cross-modal factor analysis (KCFA) with a new evaluation criterion. The proposed method estimates the latent relationship between two areas, which correspond to a missing area and its neighboring area, respectively, from known parts within the target image and realizes reconstruction of the missing textures. In order to obtain this relationship, KCFA is applied to each cluster containing similar known textures, and the optimal cluster is used for reconstructing each target missing area. Experimental results show improvements of KCFA-based reconstruction method over previously reported methods.

The article entitled "Image Demosaicing Using Content and Colour-Correlation Analysis" proposes a content adaptive demosaicing strategy utilizing structure analysis and correlation between the red, green and blue planes. These two aspects are used for the classification of a block of pixels to generated trained filters. The proposed method aims to reconstruct a high quality demosaiced image from a Bayer pattern in a colour filter array efficiently. Experimental results show that the proposed strategy performs comparatively as more expensive methods.

The article entitled “Compressed Sensing by Collaborative Reconstruction on Overcomplete Dictionary” attempts to integrate collaborative mechanism into the block-based compressed sensing reconstruction of natural images. By introducing nonlocal self-similarity information, the proposed collaborative method enhances the accuracy and the stability when recovering the sparse representations of image blocks on an overcomplete dictionary from the random measurements. The method contains two collaborative processes which are derived from two nonlocal self-similarity models: the jointly sparse model and the autoregressive model. Based on result analysis, these collaborative models show good potential of applying collaboration-based methods to other image enhancement and restoration applications.

The article entitled "MR Image Reconstruction Based on Wavelet and Nonlocal Total Variation using Split Bregman Algorithm" introduces an efficient algorithm for magnetic resonance (MR) image reconstruction. The proposed method minimizes a linear combination of nonlocal total variation, least square data fitting term and wavelet sparsity terms to reconstruct the MR image from under-sampled k-space data. The nonlocal total variation and wavelet sparsity are taken as the hybrid L1-regularization functional and solving it using Split Bregman iteration. The proposed algorithm is compared with previous methods in term of the reconstruction accuracy and computational complexity. The comparison results demonstrate the superiority of the proposed algorithm for compressed MR image reconstruction.

The article entitled “Image Compressive Sensing Recovery Using Adaptively Learned Sparsifying Basis via L0 Minimization” investigates a new framework incorporating patch-based redundant sparse representation into compressive sensing recovery of natural images. Instead of exploiting a set of fixed bases as in most conventional recovery methods, the framework characterize the redundant sparse representation using adaptively learned sprarsifying basis via L0 minimization. This approach greatly reduces blocking artifacts and confines the compressive sensing solution space. In addition to that, the framework also develops a split Bregman iteration based method to solve the L0 minimization efficiently. The framework exhibits good convergence property and significant improvements over many state-of-the-art methods.

The article entitled "A perceptual image completion approach based on a hierarchical optimization scheme" aims at introducing a novel efficient approach for high-quality and fast image restoration by combining both a greedy strategy